APPENDIX 36

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CURRENT STATUS AND LONG-TERM TRENDS IN WATER QUALITY AND LIVING RESOURCES IN THE VIRGINIA TRIBUTARIES AND CHESAPEAKE BAY MAINSTEM FROM 1985 THROUGH 2007

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I. Introduction

The period prior to the implementation of the Chesapeake Bay Monitoring Program was characterized by a marked decline in the water quality of the Chesapeake Bay. The disappearance of submerged aquatic vegetation in certain regions of the Bay, declines in the abundance of some commercially and recreationally important species, increases in the incidence of low dissolved oxygen events, changes in the Bay's food web, and other ecological problems were related to deteriorating water quality (e.g. USEPA, 1982,1983;Officer et al.,1984; Orth and Moore, 1984). The results of concentrated research efforts in the late 1970s and early 1980s stimulated the establishment of Federal and state directives to better manage the Chesapeake Bay watershed. By way of the Chesapeake Bay Agreements of 1983, 1987 and 2000, the State of Maryland, the Commonwealths of Virginia and Pennsylvania, and the District of Columbia, agreed to share the responsibility for improving environmental conditions in the Chesapeake Bay. As part of these agreements, a long-term monitoring program of the Chesapeake Bay was established and maintained in order to: 1) track long-term trends in water quality and living resource conditions over time, 2) assess current water quality and living resource conditions, and 3) establish linkages between water quality and living resources communities. By tracking long-term trends in water quality and living resources, managers may be able to determine if changes in water quality and living resource conditions have occurred over time and if those changes are a reflection of management actions. Assessments of current status may allow managers to identify regions of concern that could benefit from the implementation of pollution abatement or management strategies. By identifying linkages between water quality and living resources it may be possible for managers to determine the impact of water quality management on living resource communities.

Water quality and living resource monitoring in the Virginia main stem and tributaries began in 1985 and continues to the present. Detailed assessments of the status and long-term trends in water quality and living resources in Chesapeake Bay and its tributaries have been previously conducted (Alden et al., 1991,1992; Carpenter and Lane, 1998; Dauer, 1997; Dauer et al., 1998a,1998b, 2002b; Lane et al.,1998; Marshall, 1994,1996; Marshall and Burchardt, 1998, 2003, 2004a, 2004b, 2005; Marshall et al., 1998;2005a;2005b;2006). This report summarizes the status of and long-term trends in water quality and living resource conditions for the Virginia tributaries through 2006 and updates the previous reports (Dauer et al., 2005a, 2005b, 2005c;2007).

II. Methods and Materials

A. Monitoring Program Descriptions

Non-tidal water quality samples were collected from 1988 through 2005 at six stations at or near the fall-line in each of the major tributaries as part of the U. S. Geological Survey's (USGS) and the Virginia Department of Environmental Quality's (DEQ) River Input Monitoring Program (Figure 1). Tidal water quality was regularly monitored at 28 sites in the Bay Mainstem and at 27 sites in the James, York and Rappahannock rivers (Figure 2) beginning in July, 1985 and continuing through 2006. Six permanent water quality monitoring sites were established in the Elizabeth River in 1989 and an additional six were added to the Elizabeth River in 1998 (Figure 2). Details of changes in the monitoring program sampling regime are provided elsewhere (Dauer et al., 2005a, 2005b, 2005c) while sample collection and processing protocols are provided on the World Wide Web at http://www.chesapeakebay.net/qualityassurance.aspx.

Phytoplankton monitoring was conducted at seven stations in the Chesapeake Bay Mainstem beginning in 1985 and at six sites in the major tributaries beginning in 1986 (Figure 3). Two phytoplankton monitoring programs stations (SBE5 and SBE2) were added in the Elizabeth River in 1989 although SBE2 was eventually discontinued. Epi-fluorescent autotrophic picoplankton and C^{14} primary productivity analysis were added to all stations in 1989. Details of changes in the monitoring program, field sampling and laboratory procedures are described by Dauer et al. (2005a, 2005b, 2005c).

Benthic monitoring was conducted at sixteen fixed point stations in the lower Chesapeake Bay Mainstem and its tributaries beginning in 1985. Sampling at five additional stations, two in the Elizabeth River and one in each of the three other tributaries, began in 1989 (Figure 3). Details of, and changes to, the fixed point monitoring program sampling regime and laboratory procedures are described by Dauer et al. (2005a, 2005b, 2005c).

In 1996, the benthic monitoring program was modified to add a probability-based sampling regime to supplement data collected at fixed-point stations and estimate the area of Chesapeake Bay and its tributaries that met restoration goals as indicated by the B-IBI (Ranasinghe et al., 1994; Weisberg et al., 1997; Alden et al., 2002). Data are collected at 25 randomly allocated stations in each of four separate strata in Virginia: 1) the James River, 2) the York River (including the Pamunkey and Mattaponi rivers), 3) the Rappahannock River, and 4) the Mainstem of the Chesapeake Bay. An additional set of 25 random locations have been collected in the Elizabeth River as a part of DEQ's Elizabeth River Monitoring Program beginning in 1999. Probability-based monitoring data are used to assess biological impairment in Chesapeake Bay at different spatial scales on an annual basis. Details of the sampling, laboratory and assessment protocols are provided in Dauer et al. (2005a,2005b,2005c) and Llansó et al. (2005). Further information on all of the monitoring programs can be found at www.chesapeakebay.net.

B. Statistical Analysis

Tabular summaries of land use coverages are modified from data provided by the USEPA's Chesapeake Bay Program. Discharged point source nutrients were obtained from the Central Office of the Virginia Department of Environmental Quality. A comparison of the relative importance of point and non-point sources was made by comparing estimates of discharged loadings of nutrients and sediments generated for the Year 2007 Progress Run of the Chesapeake Bay Watershed Model available on the WWW at www.chesapeakebay.net/data_modeling.aspx. Percent changes in these estimates over the last 22 years were made using 1985 Model Assessment Run values as a baseline.

To ensure that long-term trends in water quality and living resource data are correctly interpreted, a unified approach for conducting the statistical analyses was used based on guidelines developed by the CBP Monitoring Subcommittee's Tidal Monitoring and Assessment Workgroup. For both status and trend analyses, the stations were grouped into groups or segments based on the segmentation scheme developed by the Chesapeake Bay Program's Data Analysis Workgroup (Figure 2) and data were analyzed for different time periods or "seasons" as defined for each monitoring component in Table 1.

Status of all tidal water quality parameters except dissolved oxygen parameters for each Chesapeake Bay program segment was determined using two methods: 1) the relative status as described in Dauer et al. (2005a,2005b, 2005c), and 2) by comparing three year median values during the SAV growing season to SAV habitat criteria (see Table 2) using a Mann-Whitney U-test. Status of dissolved oxygen was determined by calculating the mean of the last three years (2005 through 2007) of bottom measurements collected during the Summer months (June through September) and classifying them as follows: mean values equal to or below 2 mg/L were classified as Poor, values between 2 and less than 5 mg/L were Fair, and values equal to or greater than 5 were Good. Note that the terms Good, Fair, and Poor used in conjunction with relative status are statistical classifications for comparison between areas of similar salinity within Chesapeake Bay. Though useful in comparing current conditions among different areas of Chesapeake Bay, these terms are not absolute evaluations but only appraisals relative to other areas of what is generally believed to be a degraded system.

Status characterizations for phytoplankton communities were determined using the phytoplankton Index of Biotic Integrity or P-IBI (Buchanan et al., 2005). Status was assessed using station means of the P-IBI for the three year period from 2004 through 2006. Phytoplankton communities were classified as follows: (1) Poor for P-IBI values less than or equal to 2.00; (2) Fair-Poor for values greater than 2.00 and less than or equal to 2.67; (3) Fair for values greater then 2.67 and less than or equal to 3.00; (4) Fair-Good for values greater than 3.00 and less than or equal to 4.00; and (5) Good for values greater than 4.00.

Status of benthic communities at each station was characterized using the three-year mean value (2005 through 2007) of the B-IBI (Weisberg et al., 1997) and classified as follows: values less than or equal to 2 were classified as severely degraded, values greater than 2.0 to 2.6 were classified as degraded, values greater than 2.6 but less than 3.0 were classified as marginal, and values of 3.0 or more were classified as meeting goals. Status of benthic communities was also quantified by using the probability-based sampling to estimate the bottom area of all strata populated by benthos classified as impaired using the B-IBI (Llansó et al., 2007).

Trend analyses of non-tidal water quality parameters used a seven parameter regression model that took into account the effects of flow, time, seasonal effects and other predictors conducted on flow-adjusted concentrations (Langland et al., 2006). Trend analyses of freshwater flow at the fall-line were conducted using a seasonal Kendall test for monotonic trends (Gilbert, 1987). Trend analyses of tidal water quality parameters in the tributaries were conducted using a "blocked" seasonal Kendall approach (Gilbert, 1987) for nutrients in order to account for method changes early in the program and using a seasonal Kendall test for monotonic trends and the Van Belle and Hughes tests for homogeneity of trends between stations, seasons, and station-season combinations for non-nutrient parameters in the tributaries and all water quality parameters in the Chesapeake Bay

Mainstem (Gilbert, 1987). Trend analyses of bottom dissolved oxygen measurements were conducted using only data collected during the Summer (June through September) season. Trend analyses for living resources used the Seasonal Kendall test.

III. Results and Discussion

A. James River Basin

1. Basin Characteristics

The James River basin has the largest population, the highest population density, the largest percentage of developed land, and the largest percentage of land with impervious surfaces of the three Virginia tributaries while at the same time having the highest total area and percentage of forested land, and the lowest percentage of agricultural land (Table 3A). Above the fall-line, the James River is predominantly rural with the dominant land use type being forest coupled with some agricultural lands. The tidal portion of the river is characterized by two large urbanized regions (Richmond and Hampton Roads) with high population densities, higher percentages of impervious surfaces, relatively lower forest cover and fewer riparian buffer miles separated by large areas of predominantly forest land and open water with some agricultural land (Table 3B).

Above the fall-line, model estimates of non-point sources accounted for over 90% of the 23,754,745 lb/yr of nitrogen loads and 86% of the 2,915,295 lb/yr of phosphorus loads entering the James River in 2007 (Table 4). Point source estimates accounted for 55% of the 25,253,407 lb/yr of the total nitrogen load entering the James River below the fall-line while non-point source loadings accounted for most (40%) of the 2,309,500 lb/yr of total phosphorus load (Table 4). Nutrient reduction activities are estimated to have resulted in 13% and 27% reductions in total nitrogen loading since 1985 above and below the fall-line, respectively (Table 4). These reductions were due primarily to reductions in non-point sources above the fall-line and point source loadings below the fall-line. Nutrient reductions activities resulted in a 17% and 56% reduction in total phosphorus loadings since 1985, above and below the fall-line, respectively (Table 4). Reductions above the fall-line were due to reductions in non-point source loadings while those below the fall-line were probably due to increased point source controls.

Annual discharged point source loadings of nitrogen were from five to seven times higher below the fall-line (BFL) than above the fall-line (AFL). Annual AFL point source loadings of total nitrogen have declined steadily from nearly 3,500,000 lb/yr in 1984 to just under 2,800,000 lb/yr in (Figure 4A). Following an initial increase from around 20,200,000 lb/yr in 1984 to over 25,000,000 lb/yr in 1989, BFL point source loadings declined substantially to stabilize at values of from 11,000,000 to 13,000,000 lb/yr during the last decade (Figure 4B).

Annual point source loadings of phosphorus were generally twice as high below the fall-line (BFL) than above the fall-line (AFL). AFL total phosphorus loadings were at or near 790,000 lb/yr prior to 1988 but declined sharply during the next two years to nearly 420,000 lb/yr in 1990. Following this decline point source phosphorus loads rose steadily to around 755,000 lb/yr in 2004 but have declined again substantially during the last two years to just over 400,000 lb/yr in 2006 (Figure 5).

2. Water Quality

There were no significant trends in freshwater flow in the James or Appomattox or Chickahominy rivers at the fall-line ($p > 0.01$; Seasonal Kendall test). In general, water quality above the fall-line in the James River appears to be improving as indicated by the decreasing trends in concentrations of nitrate-nitrites, total phosphorus and dissolved inorganic phosphorus parameters. No trends in nutrients or suspended solids were observed at the fall-line in the Appomattox or Chickahominy rivers (Table 5).

Relative status of most nutrients in the tidal James River was Good or Fair except with status generally being better in the upstream segments (Figure 6). Relative status of surface chlorophyll *a* was Good in all segments except the Appomattox River (APPTF) and the James River Mouth (JMSPH) where it was Poor and in the Chickahominy River (CHKOH) where it was Fair. Status of total suspended solids and Secchi depth was Fair or Poor throughout the James River but status of bottom dissolved oxygen was Good in all segments (Figure 7). Most long-term and post method change trends in nutrients observed indicated improving water quality conditions except in the Upper James River (JMSTF2) where degrading trends in surface and bottom total nitrogen were detected during the post-method change period and in the Lower James River where degrading trends in surface and bottom dissolved inorganic phosphorus were detected (Figure 6). Improving long-term trends in surface chlorophyll *a* were detected in the Chickahominy River (CHKOH) and the Upper James River (JMSTF1) but a degrading trend in this parameter was detected at the James River Mouth (JMSPH). Degrading trends in bottom total suspended solids were detected in the Upper James River (JSMTF2) and in the Lower James River (JMSMH) while degrading trends in secchi depth were detected in both segments of the Upper James River, the Chickahominy River (CHKOH), and at the James River Mouth (JMSPH). Improving trends in Summer bottom dissolved oxygen were detected in the Appomattox River (APPTF) and at the James River Mouth (JMSPH) (Figure 7).

SAV habitat requirements for nutrients, where applicable, were borderline or not met in all segments except in the Appomattox River (APPTF) and the Chickahominy (CHKOH) where the habitat requirement for surface dissolved inorganic phosphorus were met (Figure 8) SAV habitat requirements for surface chlorophyll *a* were met in all segments except in the Appomattox River (APPTF) where this parameter was borderline. SAV habitat requirements were not met or borderline for all segments for both surface total suspended solids and secchi depth except at the James River Mouth (JMSPH) were the requirement for surface total suspended solids was met (Figure 8). Degrading post method change trends were detected in surface total nitrogen and surface dissolved inorganic nitrogen in the Upper James River (JMSTF2) and the Chickahominy River (CHKOH) during the SAV growing season. Trend analysis indicated improvements in surface dissolved inorganic phosphorus in the Appomattox River and in the Upper James River (JMSTF2), however a degrading trend in this parameter was detected in the Lower James River (JMSPH). Improving trends in surface chlorophyll *a* were detected in the Upper James River (JMSTF1) and the Chickahominy River (CHKOH) during the SAV growing season. Although no trends were detected in total suspended solids, degrading trends in secchi depth were detected in all of the upper segments of the James River (APPTF, JMSTF2, JMSTF1 and CHKOH) as well as the James River Mouth (JMSPH). An improving trend in bottom dissolved oxygen was detected in the James River Mouth (JMSPH) during the SAV growing season (Figure 8).

Status of all nutrients was either Fair or Poor in throughout of the Elizabeth River except for surface and bottom dissolved inorganic nitrogen where it was Good (Figure 9). Status of chlorophyll *a* was Poor in the Western Branch (WBEMH) and Lafayette River (LAFMH), Fair in the Eastern Branch (EBEMH) and Elizabeth River main stem (ELIPH) and Good in the Southern Branch (SBEMH). Status for surface and bottom total suspended solids was Fair or Poor in all segments except for bottom total suspended solids in the Southern Branch (SBEMH) and Eastern Branch (EBEMH). Status of Secchi depth was Poor throughout the Elizabeth River while the status of dissolved oxygen was Good or Fair (Figure 10).

No significant trends in nutrients were detected in the Western Branch (WBEMH), or the Lafayette River (LAFMH). However improving trends in either surface and/or bottom total nitrogen and dissolved inorganic nitrogen were detected in the Southern Branch (SBEMH), the Eastern Branch (EBEMH) and the Elizabeth River Mainstem (ELIPH). Improving trends in surface and/or bottom total phosphorus and dissolved inorganic phosphorus were also detected in these two segments (Figure 9). A degrading trend in bottom total nitrogen was detected in the Elizabeth River Mainstem (ELIPH), as was a post method change improving trend in bottom dissolved inorganic nitrogen (Figure 9). There were no significant trends in chlorophyll *a* in the Elizabeth River. Improving trends in surface and bottom total suspended solids were observed in the Southern Branch (SBEMH), Eastern Branch (EBEMH) and Elizabeth River main stem (ELIPH). A degrading trend in Secchi depth was detected in the Elizabeth River Mainstem (ELIPH).

SAV habitat requirement for nutrients was not met or borderline in all segments of the Elizabeth River except in the Western Branch were surface dissolved inorganic nitrogen met the criterion (Figure 11). The SAV habitat requirement for chlorophyll *a* was met in most segments of the Elizabeth River. For surface total suspended solids, SAV habitat requirement was met in the Southern Branch (SBEMH) and Eastern Branch (EBEMH) but not met in the Western Branch. The SAV habitat requirement was borderline or not met in all segments for Secchi depth (Figure 11). Status of bottom dissolved oxygen during the SAV growing season was Good.

With respect to nutrients during SAV growing season, improving trends were observed in surface nitrogen parameters in the Southern Branch (SBEMH) and Eastern Branch (EBEMH) and for surface total phosphorus in the Southern Branch (SBEMH). Degrading trends in surface total and dissolved inorganic nitrogen were detected in the Elizabeth River Mainstem (ELIPH). An improving trend and a degrading trend in surface chlorophyll *a* were detected in the Southern Branch (SBEMH) and Eastern Branch (EBEMH), respectively. Although an improving trend in surface total suspended solids was detected in the Elizabeth River Mainstem (ELIPH), a degrading trend in Secchi depth was detected in the same segment.

3. Living Resources

Status of phytoplankton communities based on the P-IBI was classified as Fair to Poor at all stations in the James River and Elizabeth River and a degrading trend in the P-IBI was detected at station SBE5 in the Southern Branch of the Elizabeth River (Figure 12). Degrading trends in cyanobacteria abundance were also detected at nearly all stations in this basin along with degrading trends in primary productivity at station TF5.5 and the Margalef diversity index at station RET5.1. Improving trends in the biomass to abundance ratio were detected in all stations of the James River excluding station SBE5 in the Elizabeth River (SBEMH), as were improving trends in chlorophyte and picoplankton biomass at stations TF5.5 in the Upper James River (segment JMSTF1) and station RET5.1 in the Middle James River (JMSOH) (Figure 12) . Two major concerns are indicated in this review. Both an upstream and a downstream station (TF5.5, LE5.5) indicated unfavorable increased biomass trends in cyanobacteria. This taxonomic group contains several major bloom produces and a few potentially toxic species. Their continued increased presence and biomass levels would be negative factors affecting water quality and biota in the James River. The second concern is the increased biomass trend in dinoflagellates downstream at station LE5.5. This group also contains several potential harmful species. This was evident in 2007 when major blooms of *Cochlodinium polykrikoides* occurred in the Elizabeth, Lafayette, and lower James rivers. Previous blooms of this species have been common in these rivers the past decade (Marshall et al., 2008) and have also taken place in August 2008. A similar negative trend in the lower James was the increased chlorophyll *a* levels accompanying this development.

The B-IBI met restoration goals at only two stations in the main stem of James River: station LE5.1 in the Middle James River (JMSOH) and, station LE5.4 in the Lower James River (JMSMH). Status of the B-IBI at all other stations in the James River was either degraded or marginal. Status of the B-IBI at both stations in the Elizabeth River was degraded (Figure 13). Improving trends in the B-IBI were detected at station RET5.2 in the Middle James River (JMSOH) and at stations SBE5 in the Southern Branch (SBEMH) of the Elizabeth River (Figure 13). In 2007, results of the probability-based benthic monitoring indicate that 68% of the total area of the James River is degraded (Llanso et al., 2007). Previous studies suggest that anthropogenic contaminant may account for much of the degradation in the James River particularly in the Elizabeth River (Dauer et al., 2005a; Llansó et al.,2005).

4. Management Issues

Trends at the fall-line indicate that in general water quality is improving in the non-tidal portions of the James River basin with respect to nutrient concentrations although no change in suspended solids was observed. Nutrients in the tidal portions of this estuary, although not as elevated as in other tributaries, do exceed desirable levels in some areas. Reductions in non-point source loadings as indicated by the reductions in fall-line nutrient concentrations above the fall-line coupled with declines in point sources loadings of nutrients both above and below the fall-line are probably linked to the high water quality with respect to nutrients found in the James River. These reductions coupled with naturally high freshwater flow input maintain nutrients at levels which are comparably better than many other areas in the Chesapeake Bay watershed. Despite the improvements, water clarity in the James River is consistently Poor and continues to decline in many areas of this tributary. The source of problems in water clarity is at least in part due to Poor conditions with respect to total suspended solids.

Despite the apparent improvements in water quality, living resources conditions in the James River are degraded and declining in some areas. Phytoplankton communities throughout the James River were characterized as Fair-Poor at all stations and conditions may be continuing to degrade as indicated by widespread degrading trends in cyanobacteria biomass although some improvements in phytoplankton communities were indicated. The benthos at most stations in the James River was marginal or degraded and probability-based benthic monitoring indicated that a high percentage (68%) of the total area of the river was degraded due in part to anthropogenic contamination (Llansó et al., 2008).

The Elizabeth River is highly impacted with respect to nutrients, water clarity and chlorophyll *a* in some areas. Intense urbanization resulting in high non-point source runoff coupled with high point source nutrient loadings result in the Poor water quality in this tributary. The degrading trends in the P-IBI in the Elizabeth River and the increasing trend in cyanobacteria biomass in the Elizabeth River are an important concern. At the level of the entire watershed, 72% of the river is characterized as having degraded benthos (Dauer, 2008). Although severely impaired, the Elizabeth River is improving at the upper reach station in the Southern Branch (SBE5). The primary stress to these communities appears to be anthropogenic contamination due to a variety of sources including historical contamination, municipal and industrial point sources, non-point source storm water run-off, and automobile emissions. Recent BMPs and reductions in point source loadings may be ameliorating both the problems with water quality and living resource conditions in some areas and expansion of these practices should result in further improvements.

B. York River Basin

1. Basin Characteristics

Although the York River watershed has the second highest total area and percentage of developed land and the second highest overall population density of all three of the Virginia tributaries, it is predominantly rural as indicated by the high percentages of forested and agricultural land with forested land accounting for over 60% of the total area. In addition, the York River has the highest percentages of open water and wetlands of all of the Virginia tributaries, as well as, the highest percentage of shoreline with a riparian buffer (Table 3A). Total area of developed land in all sub-watersheds of the York River was low and percent area of developed land was comparable between sub-watersheds. Total areas and percentages of impervious surface were always less than 3% of the total sub-watershed area. Total area and percentages of total sub-watershed area in agricultural land was generally higher in the upstream and non-tidal portions of the Pamunkey and Mattaponi rivers than in the tidal portion of the York River. Forested land decreases substantially moving downstream to the Lower Tidal York River both in total area and percent of the total sub-watershed area due primarily to an increase in open water (Table 3C).

Based on watershed model estimates, non-point sources accounted for 98% of the approximately 5,126,000 lb/yr of AFL total nitrogen loadings to the York River. There has been an estimated 16% reduction in AFL non-point source total nitrogen loadings while estimates of point source nitrogen loads increased 51% (Table 4). Non-point sources accounted for 76% of over 5,613,000 lb/yr of BFL total nitrogen loadings to the York River. Model estimates of non-point source BFL total nitrogen loads decreased 22% but point source nitrogen loadings increased 71%, respectively from 1985 through 2007 (Table 4).

Non-point sources accounted for 93% of nearly 512,500 lb/yr of the AFL total phosphorus loads and 74% of the BFL total phosphorus loads to the York River in 2007. Nutrient reduction strategies and the phosphate ban have resulted in an estimated overall reduction of 12% and 30% in non-point source loadings above and below the fall-line, respectively (Table 4). Estimates of point source loadings have increased 31% above the fall-line but decreased 54% below the fall-line (Table 4).

AFL point source loadings showed a general increase from around 112,000 lb/yr in 1984 to 213,000 lb/yr in 2000 followed by a mostly steady decline to approximately 128,000 lb/yr in 2006 (Figure 14A) BFL point source loadings of nitrogen initially declined from around 1,260,000 lb/yr in 1984 to approximately 650,000 in 1989. Thereafter, however, point source nitrogen loadings exceeded 1,000,000 lb/yr in 1990 and rose fairly steadily to reach a maximum of over 1,500,000 lb/yr in 1999 after which they dropped to below 1,000,000 lb/yr in 2001. However, during the last four years BFL point source nitrogen loadings increased steadily to reach a maximum of nearly 1,340,000 lb/yr in 2006 (Figure 14B).

AFL point source phosphorus loadings declined from approximately 37,500 lb/yr in 1984 to just under 25,000 lb/yr in 1991 but increased thereafter to reach a maximum of nearly 62,500 lb/yr in 2005. AFL point source phosphorus loadings declined sharply again in 2006 to approximately 34,000 lb/yr in 2006 (Figure 15A). BFL point source phosphorus loads declined from over 400,000 lb/yr in 1984 to 120,000 lb/yr in 1990 but then increasing to levels at or above 132,000 lb/yr until 2001 when loadings decreased to levels which have remained below 125,000 lb/yr (Figure 15B).

2. Water Quality

There were no trends in freshwater flow in either the Pamunkey or Mattaponi rivers ($p>0.01$; seasonal Kendall test). Water quality conditions at the fall-line in the Pamunkey River appear to be degrading as indicated by the increasing trends in flow adjusted concentrations of nitrogen and phosphorus parameters observed at the fall-line station near Hanover. No trends in water quality were detected at the fall-line in the Mattaponi River near Beulahville (Table 5).

Status of nitrogen parameters was Fair or Good in all segments. Status of phosphorus parameters was Good in the Upper Pamunkey River (PMKTF), the Upper Mattaponi River (MPNTF) and Mobjack Bay (MOBPH) but only Fair or Poor in the lower segments of the Pamunkey and Mattaponi (PMKOH and MPNOH) and the Lower York River (YRKPH). Status of phosphorus parameters in the Middle York River (YRKMH) was generally Poor (Figure 16). Status of surface chlorophyll *a* was Good in the Pamunkey River and Mattaponi River segments, but Fair in remaining segments. Status of total suspended solids was Poor or Fair in most segments except in the Upper Mattaponi River (MPNTF) where it was Good. Status of secchi depth was Poor in most segments of the York River except in the upper segments of Pamunkey and Mattaponi rivers where it was Fair and Good, respectively. Summer bottom dissolved oxygen status was Good or Fair in all segments (Figure 17).

Degrading long-term or post method change trends in surface and/or bottom nitrogen parameters were detected in all segments except Mobjack Bay (MOBPH) where improving trends in both total and dissolved inorganic nitrogen were detected. Degrading long term trends were detected in surface or bottom total phosphorus in the Upper and Lower Pamunkey River (PMKTF and PMKOH) and in the Middle York River (YRKMH) and Lower York River (YRKPH) while improving trends in both surface and bottom total phosphorus were detected in Mobjack Bay (MOBPH). Post method change improving trends in surface and bottom dissolved inorganic phosphorus were detected in the Upper Pamunkey River (PMKTF) and Upper Mattaponi River (MPNTF) while long-term degrading trends in surface and bottom dissolved inorganic phosphorus were detected in the Middle York River (YRKMH) (Figure 17). A degrading trend in surface chlorophyll *a* was detected in the Lower York River (YRKPH) while improving trends in bottom and/or surface total suspended solids were detected in the Upper Pamunkey River (YRKMH) and Mobjack Bay (MOBPH). Degrading trends in Secchi depth were detected in most segments (Figure 17)

SAV habitat requirements for nutrients in most segments were either met or were borderline except in the Middle York River (YRKMH) where the requirement for surface dissolved inorganic phosphorus was not met. Surface chlorophyll *a* met the SAV habitat requirement in all segments while surface total suspended solids did not meet the requirements in the Lower Pamunkey River (PMKOH), the Lower Mattaponi River (MPNOH), the Middle York River (YRKMH), and Mobjack Bay (MOBPH). Secchi depth was borderline or failed to meet the SAV criteria in most segments except the Upper Mattaponi (Figure 18). During the SAV growing season a degrading trend in surface total nitrogen was detected in the Lower York River while an improving post-method change trend was detected in Mobjack Bay (MOBPH). Degrading trends in phosphorus parameters were detected in the Lower Pamunkey River (PMKOH) and the Middle York River (YRKPH) while an improving trend was detected in the Upper Mattaponi River (MPNTF). However, an improving post-method change trend was detected in Mobjack Bay (MOBPH). There were no trends in surface chlorophyll *a* during the SAV growing season. Improving trends in surface total suspended solids were detected in the Lower Pamunkey River (PMKOH) and Mobjack Bay (MOBPH). Degrading trends in Secchi depth were detected in the Lower York River (YRKPH) and Mobjack Bay (MOBPH) (figure 18).

3. Living Resources

Status of the phytoplankton communities based on the P-IBI was Fair at station TF4.2 in the Upper Pamunkey River (PMKTF), Poor at station RET4.3 in the Middle York River (YRKMH) and Fair at station WE4.2 in Mobjack Bay (MOBPH) (Figure 19). There were no significant trends in the P-IBI. Improving trends in the biomass to abundance ratio and in chlorophyte abundance were detected at station TF4.2 in the Upper Pamunkey River (PMKTF) and at station RET4.3 in the

Middle York River (YRKMH). Degrading trends in primary productivity were detected at stations RET4.3 and WE4.2 and in cyanophyte biomass at all stations. A degrading trend in the Margalef diversity index was detected at station WE4.4 in Mobjack Bay (MOBPH) (Figure 19). Throughout the York River phytoplankton stations there were trends of increased cyanobacteria biomass. As noted in the James River, the cyanobacteria are represented by several potentially harmful taxa, some being toxin producers. Any further continuation of this trend is a potential water quality concern. In addition summer blooms of *Cochlodinium polykrikoides* continue to occur at downstream locations in the York and adjacent inlets. Many of these past blooms have lasted over several weeks, extending southward into the western coastal waters of Chesapeake Bay (Marshall et al. 2005b; 2008). An additional concern regarding the entry of other potentially toxic species in these waters occurred in 2007 when the toxic species *Alexandrium monilatum*, was identified during our monitoring in the lower York River and one of its sub-estuaries.

Benthic community status, as measured with the B-IBI, was Good only at station LE4.3 in the Lower York River (YRKPH) and either degraded or severely degraded at all other stations (Figure 20). An improving trend in the B-IBI was detected at station LE4.3B in the Lower York River (YRKPH) but no other trends in the B-IBI were detected (Figure 20). In 2007, results of the probability-based benthic monitoring indicate that 80% of the total area of the York River was degraded (Llansó et al.,2008). Previous studies indicate that a combination of anthropogenic contamination, eutrophication and low dissolved oxygen adversely affect benthic communities in the York River (Dauer et al., 2005b; Llansó et al.,2005).

4. Management Issues

Water quality in the non-tidal portion of the Pamunkey River appears to be degrading as indicated by increasing trends observed in both nitrogen and phosphorus parameters. Despite the generally Good relative status, increasing trends in both nitrogen and to a lesser degree phosphorus parameters indicate that water quality in the York River may be degrading possibly in response to increases in above fall-line non-point source loadings. In addition, degrading trends in nutrients may be due to increasing point source total nitrogen loads both above and below the fall-line and to increasing AFL point source total phosphorus loads. Poor water clarity is a persistent and widespread problem in the York River as indicated by the Poor relative status, the SAV habitat requirement failures of secchi depth throughout the estuary and the degrading trends observed in some segments. The source of the water clarity problem is unknown. Although the increases in point source nutrients observed were relatively small, the small total area and low flow rates of the York River may make it more susceptible to changes in point or non-point source nutrient loadings.

Phytoplankton community conditions appear to reflect Poor water quality conditions as indicated by the Fair to Poor status in the P-IBI observed through this tributary. In addition, phytoplankton communities may be continuing to degrade as indicated by the increasing trends in cyanobacteria biomass. The increases in cyanobacteria observed may adversely affect water clarity. Although sporadic in their occurrence, dinoflagellate blooms occur in the downstream areas of this tributary and are often extensive in areal coverage and in the duration of their development. On these occasions, they represent a serious negative effect on water quality and living resources of the area.

All but one of the fixed point benthic monitoring stations in the York River were degraded and probability-based sampling indicated that 80% of the bottom of the York River does not met the restoration goals (Llansó et al.,2008). Previous studies suggest that anthropogenic contamination appears to be the predominant source of stress to the benthos but eutrophication and low dissolved oxygen also play a role (Dauer et al., 2005b). There is a possibility that physical disturbance of the benthos caused by seabed mixing, a natural source of stress, may also be an important factor determining benthic community status in the York River (Dellapenna et al., 1998; 2003).

C. Rappahannock River Basin

1. Basin Characteristics

The Rappahannock River is predominantly rural with lowest overall population density and percentage of developed land of all three Virginia tributaries coupled with high percentages of agricultural and forest land use types. It has the second highest area of agricultural cropland of all three of the Virginia tributaries (Table 3A). Sub-watershed specific percentages of agricultural land were generally near or greater than 20% and decreased moving downstream from above the fall-line while percentages of forest land were above 40% and also decreased moving downstream. The percentage of shoreline with a riparian buffer was 35.6% overall and decreased moving downstream from the Upper Tidal portion of the river (Table 3D).

Non-point sources are estimated to have accounted for 95% of the nearly 5,900,000 lb/yr of total nitrogen loads above the fall-line and 92% of the nearly 4,000,000 lb/yr below the fall-line. Although the AFL point source nitrogen loads increased 43% from 1985 through 2007, non-point source loadings were reduced 17% resulting in a 16% reduction in total nitrogen above the fall-line (Table 4).

Based on model estimates, non-point sources accounted for 95% of the 579,000 lb/yr of AFL total phosphorus loads and 92% of the 306,000 lb/yr of BFL total phosphorus loads to the Rappahannock River. Management activities resulted in estimates reductions of 18% and 38% in non-point source loading above and below the fall-line, respectively (Table 4). Estimates of point source loadings decreased 60% and 79% above and below the fall-line, respectively (Table 4).

AFL point source loadings of nitrogen initially decreased overall from over 190,000 lb/yr in 1984 to 135,000 lb/yr in 1988. After this time AFL point source loadings showed a generally increasing trend to a value just over 260,000 lb/yr in 2007 (Figure 21A). In contrast, BFL total nitrogen loads showed a general increase from over 330,000 lb/yr in 1984 to nearly 470,000 lb/yr in 1989. Thereafter values typically maintained levels above 300,000 lb/yr during the period from 1990 through 2003 but thereafter declined to around 232,000 lb/yr in 2007 (Figure 21B).

Annual BFL point source loadings of phosphorus were typically higher than AFL values for the period of 1985 through 1995 but have become comparable during the last eight years following substantial and generally steady declines in both regions that began in 1989 following the phosphate ban (Figure 22A-B). AFL point source loadings of total phosphorus showed a decline from an initial

81,000 lb/yr in 1984 to about 26,000 lb/yr in 2007 (Figure 22A). BFL point source loadings of total phosphorus showed a steep drop from values at or above 115,000 lb/yr from 1984 through 1987 to just over 66,000 lb/yr in 1988. Thereafter, BFL point source total phosphorus loads have steadily declined to less that 20,000 lb/yr in the Rappahannock River (Figure 22B).

2. Water Quality

No significant trends in freshwater flow at the Rappahannock River fall-line were detected. There were no significant trends in nutrient or total suspended solids above the fall-line in the Rappahannock River (Table 5).

Relative status of nutrients was Good for all parameter/segment combinations in the Rappahannock River except for surface and bottom total phosphorus in the Middle Rappahannock River (RPPOH) where it was Fair (Figure 23). Status of chlorophyll *a* was Fair in all segments except the Upper Rappahannock River (RPPTF) where it was Good. Status of surface and bottom total suspended solids was Fair or Poor except in the Corrotoman River (CRRMH) where it was Good. Status of Secchi depth was Poor in all segments of the Rappahannock River except for the Corrotoman River (CRRMH) where it was Fair. Status of Summer bottom dissolved oxygen was Good in Upper Rappahannock River and the Middle Rappahannock River and Fair in the remaining segments Figure 24).

Degrading long-term trend were detected in bottom total nitrogen and surface total phosphorus in the Middle Rappahannock River (RPPOH) and in surface total phosphorus in the Corrotoman River (CRRMH). An improving long-term trend in surface dissolved inorganic nitrogen was detected in the Corrotoman River (CRRMH). Improving post method change trends were detected in surface and/or dissolved inorganic phosphorus in the Upper Rappahannock River (RPPTF) and the Middle Rappahannock River (RPPOH) (Figure 23). Degrading trends in surface chlorophyll *a* were detected in the Middle Rappahannock River (RPPOH) and Lower Rappahannock River (RPPMH). Although there were no trends in total suspended solids, degrading trends in secchi depth were also detected in the Middle Rappahannock River (RPPOH) and the Corrotoman River (CRRMH). Decreasing trends in salinity were detected in the Lower Rappahannock River (RPPMH) and the Corrotoman River (CRRMH) (Figure 24).

SAV habitat requirements for nutrients were met in all applicable segments. Surface chlorophyll *a* was either borderline or met the SAV habitat criteria throughout the Rappahannock River. Both surface total suspended solids and secchi depth failed to meet the SAV habitat criteria in both the Upper Rappahannock River (RPPOH) and the Middle Rappahannock River (RPPMH) but were borderline or met the criteria elsewhere. During the SAV growing season, a improving long-term trend in surface dissolved inorganic nitrogen was detected in the Corrotoman River (CRRMH) as well as degrading trends in surface chlorophyll *a* in the Middle Rappahannock River (RPPOH) and the Lower Rappahannock River (RPPMH). Degrading trends in secchi depth were observed in Lower Rappahannock River (RPPMH) and the Corrotoman River (CRRMH) (Figure 24).

3. Living Resources

Status of phytoplankton communities based on the P-IBI was Fair at station LE3.6 and Fair-Poor at station RET3.1 in the Lower Rappahannock River (RPPMH) while status was Poor at station TF3.3 also in the Middle Rappahannock River (RPPOH). There were no significant trends in the P-IBI. Improving trends in the biomass to abundance ratio were detected at all stations while degrading trends in primary productivity and cyanophyte biomass were detected at all stations. Improving trends in diatom and chlorophyte biomass were detected at station TF3.3 in the Middle Rappahannock River and station RET3.1 in the Lower Rappahannock River (RPPMH) along with an improving trend in picoplankton biomass at station LE3.6 in the Lower Rappahannock River (RPPMH). A degrading trend in the Margalef diversity index was also detected at this station. In addition to the trend of increased cyanobacteria biomass at all stations there were also increasing trends in dinoflagellate biomass. These two categories each contain potentially harmful and toxic species. Of concern would be the continuous increased biomass of these two groups and a decline in diatom biomass which presently indicated no significant trend. These increasing biomass trends were accompanied by increasing chlorophyll *a* levels.

Benthic community status met the restoration goals only at station TF3.3 in the Middle Rappahannock River (RPPOH) and in general became more degraded moving downstream with both stations in the Lower Rappahannock River (RPPMH) being severely degraded. A degrading trend in the B-IBI was detected at station RET3.1 in the Lower Rappahannock River (RPPMH) (Figure 26). Probability-based benthic monitoring results indicated that 88% of the total area of the Rappahannock River was impaired in 2007. Previous studies indicate benthic degradation in the Upper Rappahannock River appears to be the result of anthropogenic contamination while degradation in the lower segments of the river may be the result of a combination of contamination and low dissolved oxygen effects (Dauer et al., 2005c; Llansó et al.,2005).

4. Management Issues

Water quality conditions with respect to nutrients are generally Good through the Rappahannock River. Water quality problems with non-nutrient parameters were more severe in the upper tidal regions of the Rappahannock River and include Poor status and violations of SAV habitat criteria for both suspended solids and secchi depth. Water clarity may also be degrading in the lower portion of the river as evidences decreasing trends in secchi depth observed. Issues with phytoplankton communities include Poor status and degrading trends in cyanophyte biomass and primary productivity throughout the basin, as well as, Poor status and degrading trends in Margalef species diversity and dinoflagellate abundance in the lower river. The pattern of increasing trends in cyanophyte biomass is exhibited not only in each of the Virginia rivers mentioned in this report, but also the Potomac River located north of the Rappahannock River. Already major blooms of cyanobacteria occur annually in the Potomac. If the increasing trends among the cyanobacteria continue, management concerns will include the impact of any long term, extensive development of these taxa within Virginia rivers. Several of the cyanobacteria identified in Virginia rivers are potential toxin producers. One of the most common species is *Microcystis aeruginosa*, which to date has not produced major toxic blooms in the James, York, or Rappahannock Rivers, but has been associated with blooms and the toxin microcystin in several of the Virginia bays and streams bordering the Potomac River.

Status of benthic communities for fixed point monitoring stations was degraded at stations furthest downstream in the Rappahannock River probably as a result of the low dissolved oxygen in this region. Degrading trends were detected in B-IBI at the uppermost station of Lower Rappahannock River (RPPMH). In 2007, results of the probability-based monitoring results indicate that 88% of the total area of the tidal portion of the river is degraded (Llansó et al.,2008).

D. Virginia Chesapeake Bay Mainstem

1. Water Quality

Relative status of nutrients was Good for all nutrient parameter/segment combinations in the Virginia Chesapeake Bay Mainstem except for bottom total nitrogen in Pocomoke Sound (POCMH) and bottom dissolved inorganic nitrogen in the Lower Western Mainstem (CB6PH) where the status of these parameters was Fair (Figure 28). Status was of surface chlorophyll *a* was Fair in all segments but the Lower Mainstem (CB8PH) and Pocomoke Sound (POCMH) where it was Good and Poor, respectively. Status of surface and bottom total suspended solids was Good in most segments except in the Lower Eastern Mainstem (CB7PH) were status of bottom total suspended solids was Fair and in Pocomoke Sound where status of surface and bottom suspended solids was Poor and Fair, respectively. Status of Secchi depth was Fair or Poor in all segments while status of bottom dissolve oxygen was Good in all segments except the Lower Western Mainstem where it was Fair (Figure 29).

Improving trends in surface and/or bottom total nitrogen where detected during the post-method change period in all segments of the Virginia Chesapeake Bay Mainstem except the Lower Mainstem (CB8PH). Degrading post-method change trends in surface and bottom total dissolved inorganic nitrogen were detected in the Lower Mainstem (CB8PH) while improving post-method change trends in surface and bottom dissolved inorganic nitrogen were detected in Pocomoke Sound (POCMH). Improving post-method change or long-term trends in surface and/or bottom total phosphorus were detected in all segments. There were no trends in surface dissolved inorganic phosphorus except for a post-method change improving trend in bottom dissolved organic phosphorus in Pocomoke Sound (POCMH) (Figure 28). There were no significant trends in surface chlorophyll *a* in any segments. Improving trends in both surface and bottom total suspended solids were detected in the Piankatank River (PIAMH), the Lower Western Mainstem (CB6PH), and Pocomoke Sound (POCMH) while degrading trends in these two parameters were detected in the Lower Eastern Mainstem (CB7PH). Decreasing trends in both surface and bottom salinity were detected in all segments of the Virginia Chesapeake Bay Mainstem (Figure 29).

SAV habitat requirements for nutrients, surface chlorophyll a, surface total suspended solids and Secchi depth were met in all applicable segments except in the Piankatank River where Secchi depth was borderline and in Pocomoke Sound where surface total suspended solids was borderline and Secchi depth failed to meet the criterion (Figure 30). Relative status for all nutrients was Good for most segments except in Pocomoke Sound (POCMH) where the status of surface total nitrogen was Fair. Status was Fair in most segments for chlorophyll *a* and Good in most segments for surface total suspended solids. Status of Secchi depth was Poor in all but two segments where it was Fair (Figure 30). Improving post-method change trends in surface total nitrogen were detected in all segments except the Lower Mainstem (CB8PH). Improving long-term or post-method change trends in surface total phosphorus were detected in all segments except the Piankatank River (PIAMH). An improving trend in surface total suspended solids was detected in the Piankatank River (PIAMH) while degrading trends in Secchi depth were detected in all segments (Figure 30).

2. Living Resources

Status of phytoplankton communities in the Virginia Chesapeake Bay Mainstem based on the P-IBI was Fair at stations CB6.1, CB6.4 in the Lower Western Mainstem (CB6PH) and CB7.3E in the Lower Eastern Mainstem (CB7PH) and Fair-Good at station CB7.4 in the Lower Mainstem (CB8PH) (Figure 31). There were no significant trends detected in the P-IBI. Improving trends were detected in the biomass to abundance ratio at all stations except CB6.1 and in picoplankton abundance at stations CB6.1 and CB6.4 in the Lower Western Mainstem (CB6PH). Degrading trends were detected in the Margalef diversity index, primary productivity and dinoflagellate abundance at stations CB6.4 in the Lower Western Mainstem (CB6PH) and station CB7.4 in the Lower Mainstem (CB8PH). Degrading trends in cyanophyte biomass at all stations as well as degrading trends in dinoflagellate biomass at two stations (Figure 31) raises concern about blooms of potentially harmful taxa in the lower Bay ecosystem. Both of these groups represent less favorable taxa relative to the health status of the Bay. Current monitoring has to date identified a total of 37 potentially harmful species within the Chesapeake Bay and its tidal tributaries (Marshall et al.,2005a; 2005b; 2008).

Status in benthic communities at the fixed point stations was severely degraded at station CB5.4, marginal at station CB6.1and Good at all remaining stations in the Virginia Chesapeake Bay Mainstem (Figure 32). Probability-based benthic monitoring results for 2007 indicated that 32% of the total area of the Virginia Chesapeake Bay Mainstem was impaired (Llansó et al.,2008).

3. Management Issues

Nutrient conditions in the Virginia Chesapeake Bay Mainstem appear to be Good both with respect to relative status and with respect to SAV habitat requirements and also to be improving as evidenced by the decreasing trends in both total nitrogen and total phosphorus observed in all segments. Although relative status of total suspended solids was typically only Fair or Poor improving trends in this parameter were observed in several segments and the SAV criterion for this parameter was met in most segments. However, water clarity, as measured using Secchi depth, appears to be an important water quality problem in the Mainstem as relative status was only Poor or Fair in this region and degrading trends in the parameter were detected in all segments.

With respect to living resources, the Virginia Chesapeake Bay Mainstem was the least impacted of Virginia's tidal water regions. Phytoplankton community status, as measured phytoplankton P-IBI was Fair-Good at all stations. However, there are some indications that phytoplankton communities may be degrading as indicated by the increasing trends in productivity, decreasing trends in species diversity and increasing trends in cyanobacteria and dinoflagellate biomass found at several stations. With respect to the benthos, the B-IBI met the restoration goal at most stations and only 32% of the total area of Virginia Chesapeake Bay Mainstem was classified as impaired. No trends were observed for the B-IBI. Good water quality and living resource conditions coupled with the improving trends in both water quality and living resources observed suggest that reductions in both point and non-point source loadings that have occurred over the last twenty years may have resulted in improvements within the Mainstem.

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Tables

Table 1. Definitions of seasonal time periods for status and trend analyses conducted for of the tidal monitoring programs. A "x" indicates the analysis was conducted for the season and parameter group combination while a "-" indicates that no analysis was conducted. Benthic status and trend analyses were conducted on data collected from July 15 through September 30*.

		Water Quality			Plankton		Benthos	
Season	Definition	Status	Trend	SAV Goals	Status	Trend	Status	Trend
Annual	Entire year	x	x	-	x	x	-	-
SAV1	March through May and September through November	x	x	x	x	x	-	-
SAV2	April through October	x	x	-	x	x	-	-
Summer1	June through September	x	x	-	x	x	-	-
Summer2	July through September	x	x	-	x	x	x*	x*
Spring1	March through May	x	x	-	x	x	-	-
Spring2	April through June	x	x	-	x	x	-	-
Fall	October through December	-	x	-	x	x	-	-
Winter	January and February	-	x	-	x	x	-	-

Table 2. Habitat requirements for growth and survival of SAV (from Batiuk et al., 1992; 2000).

Salinity Regime	SAV Growth Season	Secchi Depth (m)	Total Suspended Solids (mg/l)	Chlorophyll *a* (µg/l)	Dissolved Inorganic Nitrogen (mg/l)	Dissolved Inorganic Phosphorus (mg/l)
Tidal Freshwater	Apr.-Oct.	<2	<15	<15	none	<0.02
Oligohaline	Apr.- Oct.	<2	<15	<15	none	<0.02
Mesohaline	Apr.-Oct.	<1.5	<15	<15	<0.15	<0.01
Polyhaline	Mar.-May, Sep.-Nov.	<1.5	<15	<15	<0.15	<0.01

Table 3. Comparison of land use and population patterns between A. Watersheds of the Virginia portion of Chesapeake Bay, B. Sub-watersheds of the James River, C. Sub-watersheds of the York River and D. Sub-watersheds of the Rappahannock River. Land use values are expressed as the total area in km^2 within each watershed or sub-watershed and in parentheses as percentages of the total area within the watershed or sub-watershed. Note that the Impervious Surface land use category encompasses portions of the other land use types. Riparian buffers are measured in km of shoreline with a 30 m riparian buffer. Population values are provided as both total number per watershed or sub-watershed and densities expressed in the number of individuals per km^2. All land use and population data presented were obtained and modified from data provided by the USEPA's Chesapeake Bay Program.

A. Watersheds of the Virginia portion of Chesapeake Bay

	Land Use Area in km^2 (percent of total)									
Watershed	Total Area	Developed	Agriculture	Forested	Open Water	Wetland	Barren	Impervious Surfaces	Riparian Buffers (%)	Pop. Number/ Density(#/km^2)
Chesapeake Bay	171,944	6,239(3.6)	48,938(28.5)	103,343(60.1)	7,415(4.3)	4,421(2.6)	1,551(0.9)	3,026(1.8)	110,134 (58.5)	15,594,241(91)
James River	27,019	1,222(4.5)	4,605(17.0)	19,119(70.8)	989(3.7)	704(2.6)	365(1.4)	511(1.9)	16,636(60.2)	2,522,583(93)
York River	8,469	192(2.3)	1,761(20.8)	5,159(60.9)	647(7.6)	575(6.8)	135(1.6)	81(1.0)	6,062(60.3)	372,488(44)
Rappahannock River	7,029	124(1.8)	2,207(31.4)	4,009(57.0)	443(6.3)	171(2.4)	75(1.1)	46(0.7)	3,672(35.6)	240,754(34)

B. Sub-watersheds of the James River

	Land Use Area in km^2 (percent of total)									
Subwatershed	Total Area	Developed	Agriculture	Forested	Open Water	Wetland	Barren	Impervious Surfaces	Riparian Buffers (%)	Pop. Number/ Density(#/km^2)
AFL Upper James	7,938	67(0.8)	1158(14.6)	6630(83.5)	44(0.6)	10(0.1)	26(0.3)	24(0.3)	4427(40)	313780(40)
AFL North of Hopewell	642	171(26.6)	127(19.8)	280(43.5)	31(4.8)	18(2.8)	16(2.4)	68(10.6)	359(33)	367126(572)
AFL Piedmont	12,362	184(1.5)	2173(17.6)	9438(76.3)	114(0.9)	212(1.7)	243(2.0)	49(0.4)	8061(40)	186360(15)
AFL Richmond	790	91(11.5)	179(22.6)	461(58.4)	23(3.0)	28(3.6)	8(1.0)	30(3.8)	478(37)	60550(77)
AFL Swift Creek	471	21(4.4)	60(12.6)	376(79.7)	8(1.6)	3(0.5)	5(1.1)	10(2.1)	346(43)	188746(400)
AFL Upper Chickahominy	787	137(17.4)	148(18.8)	394(50.0)	10(1.3)	91(11.5)	8(1.0)	49(6.3)	739(32)	85669(109)
Appomattox	212	47(22.0)	44(20.7)	101(47.6)	5(2.4)	8(2.7)	8(3.7)	19(9.0)	121(32)	84765(399)
Lower Chickahominy	430	5(1.2)	52(12.0)	277(64.5)	39(9.0)	52(12.0)	5(1.2)	2(0.4)	537(34)	10343(24)
Upper Tidal James	730	18(2.5)	135(18.4)	445(61.0)	93(12.8)	31(4.3)	5(0.7)	9(1.2)	419(34)	36769(50)
Middle Tidal James	368	13(3.5)	62(16.9)	168(45.8)	96(26.1)	28(7.7)	3(0.7)	7(1.9)	311(35)	39886(108)
Lower Tidal James	803	73(9.0)	137(17.1)	256(31.9)	272(33.9)	62(7.7)	5(0.6)	30(3.8)	371(26)	166367(207)
Nansemond	559	28(5.1)	181(32.4)	197(35.2)	60(10.6)	85(15.3)	10(1.9)	14(2.5)	248(22)	49578(89)
Elizabeth River/Hampton Roads	668	259(38.8)	114(17.1)	52(7.8)	163(24.4)	67(10.1)	13(1.9)	141(21.1)	74(9)	594760(890)

Table 3. Continued. Land use values are expressed as the total area in km^2 within each watershed or sub-watershed and in parentheses as percentages of the total area within the watershed or sub-watershed. Note that the Impervious Surface land use category encompasses portions of the other land use types. Riparian buffers are measured in km of shoreline with a 30 m riparian buffer. Population values are provided as both total number per watershed or sub-watershed and densities expressed in the number of individuals per km^2. All land use and population data presented were obtained and modified from data provided by the USEPA's Chesapeake Bay Program.

C. Sub-watersheds of the York River

	Land Use Area in km^2 (percent of total)									
Sub-watershed	Total Area	Developed	Agriculture	Forested	Open Water	Wetland	Barren	Impervious Surfaces	Riparian Buffers (%)	Pop. Number/ Density(#/km^2)
Above Fall-Line Pamunkey	2748	31(1.1)	645(23.5)	1870(68.0)	67(2.5)	75(2.7)	62(2.3)	11(0.4)	1720(65)	55111(20)
Upper Pamunkey	785	21(2.6)	243(31.0)	425(54.1)	13(1.7)	67(8.6)	13(1.7)	6(0.8)	686(74)	33911(43)
Lower Pamunkey	282	3(0.9)	44(15.6)	150(53.2)	31(11.0)	49(17.4)	5(1.8)	1(0.5)	189(38)	3696(13)
Above Fall-Line Mattaponi	1023	16(1.5)	199(19.5)	717(70.1)	10(1.0)	52(5.1)	23(2.3)	13(1.3)	816(81)	32564(32)
Upper Mattaponi	805	3(0.3)	179(22.2)	541(67.2)	10(1.3)	54(6.8)	16(1.9)	2(0.3)	774(87)	8430(10)
Lower Mattaponi	534	5(1.0)	111(20.9)	350(65.5)	23(4.4)	47(8.7)	3(0.5)	2(0.4)	482(67)	7577(14)
Upper Tidal York	523	10(2.0)	80(15.3)	293(55.9)	91(17.3)	47(8.9)	3(0.5)	5(1.0)	376(53)	23676(45)
Lower Tidal York	215	10(4.8)	26(12.0)	78(36.1)	85(39.8)	13(6.0)	0(0)	5(2.2)	91(31)	21072(98)
Mobjack Bay	671	10(1.5)	88(13.1)	272(40.5)	205(30.5)	93(13.9)	5(0.8)	5(0.7)	270(27)	24929(37)

D. Sub-watersheds of the Rappahannock River

	Land Use Area in km^2 (percent of Sub-watershed total)									
Sub-Watershed	Total Area	Developed	Agriculture	Forested	Open Water	Wetland	Barren	Impervious Surfaces	Riparian Buffers (%)	Pop. Number/ Density(#/km^2)
AFL Rappahannock	4035	57(1.4)	1466(36.3)	2463(61.0)	16(0.4)	10(0.3)	28(0.7)	16(0.4)	1470(32.2)	101306(25)
Upper Tidal Rappahannock	878	41(4.7)	223(25.4)	521(59.3)	31(3.5)	47(5.3)	16(1.8)	21(2.4)	682(41.3)	97960(112)
Middle/Lower Rappahannock	982	16(1.6)	282(28.8)	502(51.2)	85(8.7)	80(8.2)	16(1.6)	5(0.5)	825(38.7)	12373(13)
Lower Rappahannock	694	8(1.1)	155(22.4)	339(48.9)	155(22.4)	28(4.1)	13(1.9)	3(0.4)	449(37.2)	10480(15)
Mouth of Rappahannock	440	8(1.8)	80(18.2)	184(41.8)	155(35.3)	8(1.8)	5(1.2)	2(0.5)	244(32.0)	10786(24)

Table 4. Nutrient and Sediment A. Non-point Source Loadings, B. Point Source Loadings and C. Total Loadings for Virginia tributaries for 2007, modified from data retrieved from the Chesapeake Bay Program Model Output Database (www.chesapeakebay.net/data_modeling.aspx). Nitrogen and phosphorous loads are in pounds per year while sediment loads are tons per year. Percent changes compare 2007 Progress Run values to the 1985 Model Assessment Run values. All loads presented are model estimates of discharged or "end of stream" loads.

A. Non point Sources

Basin	Location	2007 Nitrogen Loads (lbs/yr)	% Change	2007 Phosphorus Loads (lbs/yr)	% Change	2007 Sediment Loads (tons/yr)	% Change
James	AFL	21,909,750	-12	2,585,439	-14	594,541	-20
	BFL	11,314,454	-6	1,378,232	-16	128,133	-8
York	AFL	5,000,624	-16	478,857	-12	214,494	-19
	BFL	4,274,430	-22	341,848	-30	70,422	-28
Rappahannock	AFL	5,623,898	-17	550,832	-18	92,758	-20
	BFL	3,667,689	-28	280,919	-38	123,698	-36

B. Point Sources

Basin	Location	2007 Nitrogen Loads (lbs/yr)	% Change	2007 Phosphorus Loads (lbs/yr)	% Change
James	AFL	1,844,996	-25	329,856	-34
	BFL	13,938,953	-38	931,268	-74
York	AFL	125,643	51	33,591	31
	BFL	1,338,599	71	117,455	-54
Rappahannock	AFL	272,467	43	28,341	-60
	BFL	310,684	-11	25,359	-79

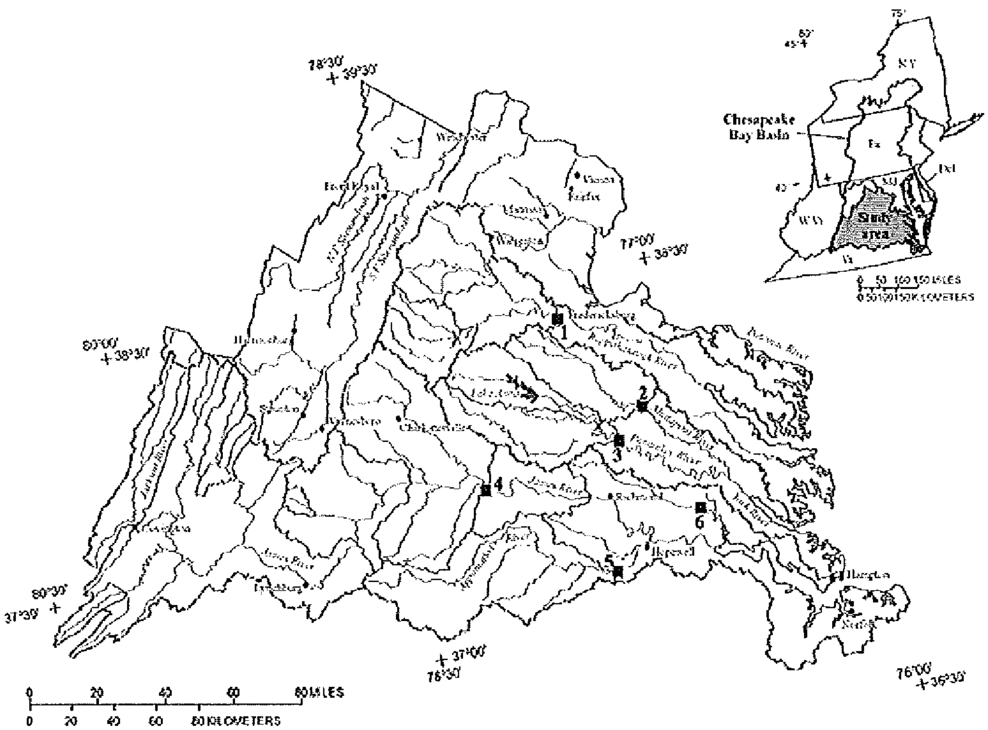
C. Total

Basin	Location	2007 Nitrogen Loads (lbs/yr)	% Change	2007 Phosphorus Loads (lbs/yr)	% Change	2007 Sediment Loads (tons/yr)	% Change
James	AFL	23,754,745	-13	2,915,295	-17	594,541	-20
	BFL	25,253,407	-27	2,309,500	-56	128,133	-8
York	AFL	5,126,267	-15	512,448	-10	214,494	-19
	BFL	5,613,029	-10	459,301	-38	70,422	-28
Rappahannock	AFL	5,896,364	-16	579,173	-22	92,758	-20
	BFL	3,978,374	-27	306,278	-47	123,698	-36

Table 5. Long-term trends in nutrients and total suspended solids at Chesapeake Bay River Input Monitoring Program stations located at or near the fall-line for each of the major Virginia tributaries for the period of 1984 through 2007. Results provided and modified from U.S. Geological Survey.

Station	Station Name	Parameter	Flow Adjusted τ Statistic	P value	Flow Adjusted % Change	Direction
02035000	James River at Cartersville	TN	-0.2598	<0.0001	-22.9	Improving
02035000	James River at Cartersville	DNO23	-0.4302	<0.0001	-35	Improving
02035000	James River at Cartersville	TP	-0.9081	<0.0001	-59.7	Improving
02035000	James River at Cartersville	DIP	-1.7364	<0.0001	-82.4	Improving
02035000	James River at Cartersville	TSS	-0.2607	0.0306	-22.9	Improving
02041650	Appomattox River at Matoaca	TN	0.0087	0.8626	0.9	No Trend
02041650	Appomattox River at Matoaca	DNO23	-0.2008	0.0968	-18.2	No Trend
02041650	Appomattox River at Matoaca	TP	0.2048	0.0123	22.7	No Trend
02041650	Appomattox River at Matoaca	DIP	-0.215	0.0309	-19.3	No Trend
02041650	Appomattox River at Matoaca	TSS	-0.067	0.4592	-6.5	No Trend
01673000	Pamunkey River near Hanover	TN	0.1451	0.0017	15.6	Degrading
01673000	Pamunkey River near Hanover	DNO23	0.393	<0.0001	48.1	Degrading
01673000	Pamunkey River near Hanover	TP	0.7053	<0.0001	102.4	Degrading
01673000	Pamunkey River near Hanover	DIP	0.7139	<0.0001	104.2	Degrading
01673000	Pamunkey River near Hanover	TSS	0.4929	0.0004	63.7	Degrading
01674500	Mattaponi River near Beulahville	TN	-0.0589	0.1542	-5.7	No Trend
01674500	Mattaponi River near Beulahville	DNO23	0.0859	0.366	9	No Trend
01674500	Mattaponi River near Beulahville	TP	-0.1455	0.0263	-13.5	Improving
01674500	Mattaponi River near Beulahville	DIP	-0.3636	<0.0001	-30.5	Improving
01674500	Mattaponi River near Beulahville	TSS	-0.0485	0.6751	-4.7	No Trend
01668000	Rappahannock River near Fredericksburg	TN	-0.1609	0.0221	-14.9	Improving
01668000	Rappahannock River near Fredericksburg	DNO23	-0.2941	0.0281	-25.5	Improving
01668000	Rappahannock River near Fredericksburg	TP	-0.3366	0.0021	-28.6	Improving
01668000	Rappahannock River near Fredericksburg	DIP	-0.1914	0.0575	-17.4	No Trend
01668000	Rappahannock River near Fredericksburg	TSS	-0.3082	0.0679	-26.5	No Trend

Figures



1 Station 01668000 - Rappahannock River near Fredericksburg
2 Station 01674500 - Mattaponi River near Beulahville
3 Station 01673000 - Pamunkey River near Hanover
4 Station 02035000 - James River at Cartersville
5 Station 02041650 - Appomattox River
6 Station 02042500 - Chickahominy River

Figure 1. Locations of the USGS/DEQ River Input Monitoring stations in each of the Virginia tributaries.

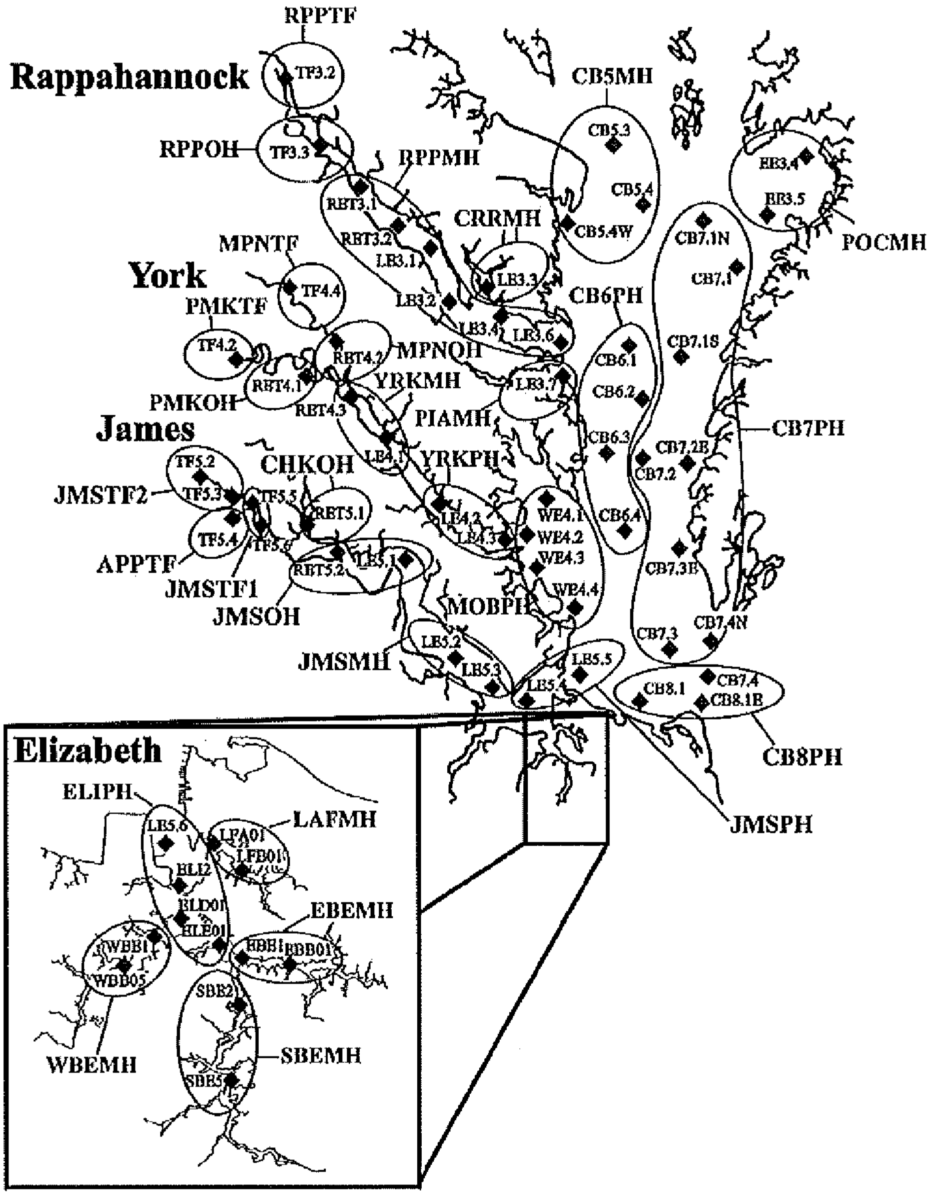


Figure 2. Map showing the locations of the water quality monitoring stations in the Virginia tributaries and the Lower Chesapeake Bay main stem used in the statistical analyses. Also shown are ellipses that delineate the Chesapeake Bay Program segmentation scheme.

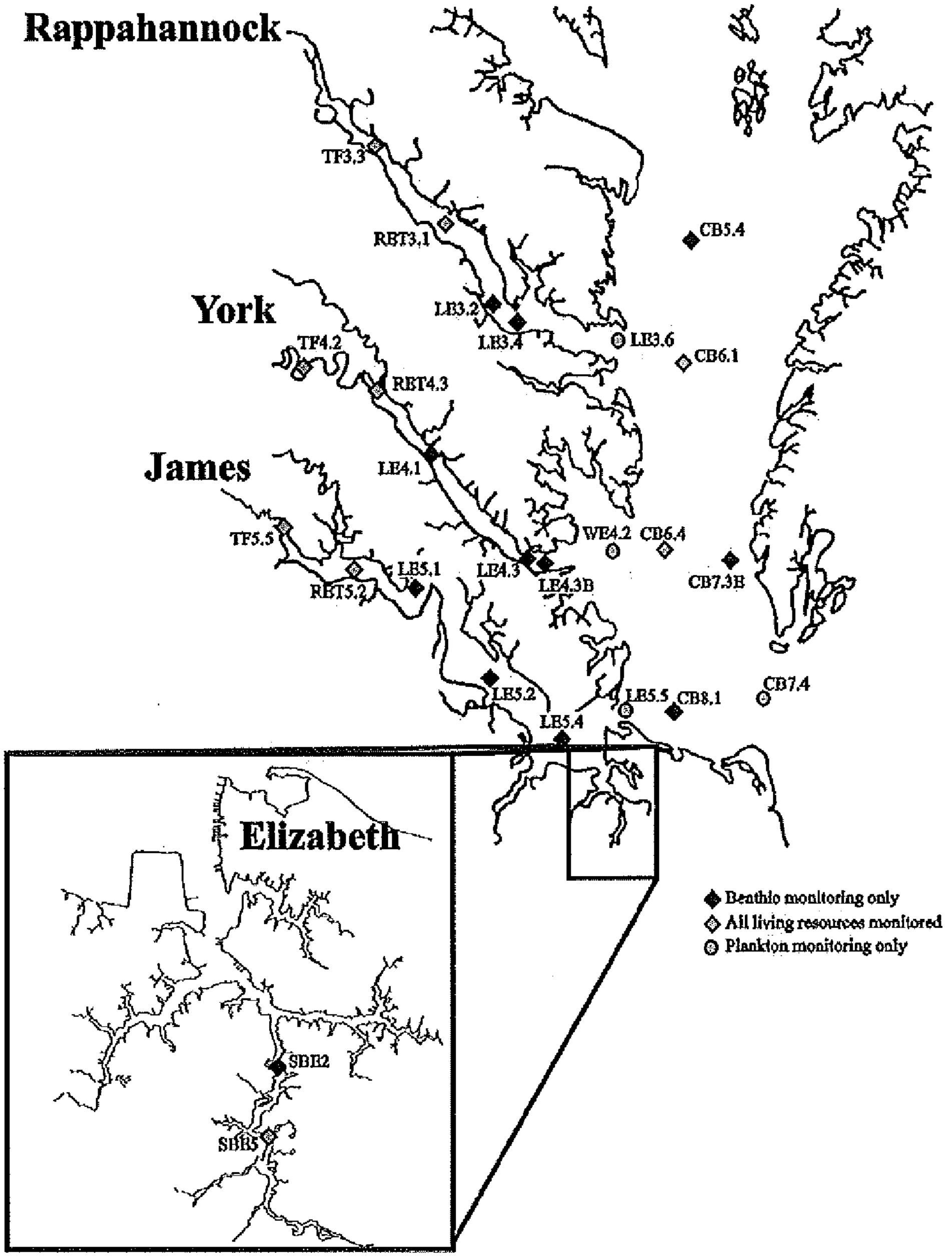
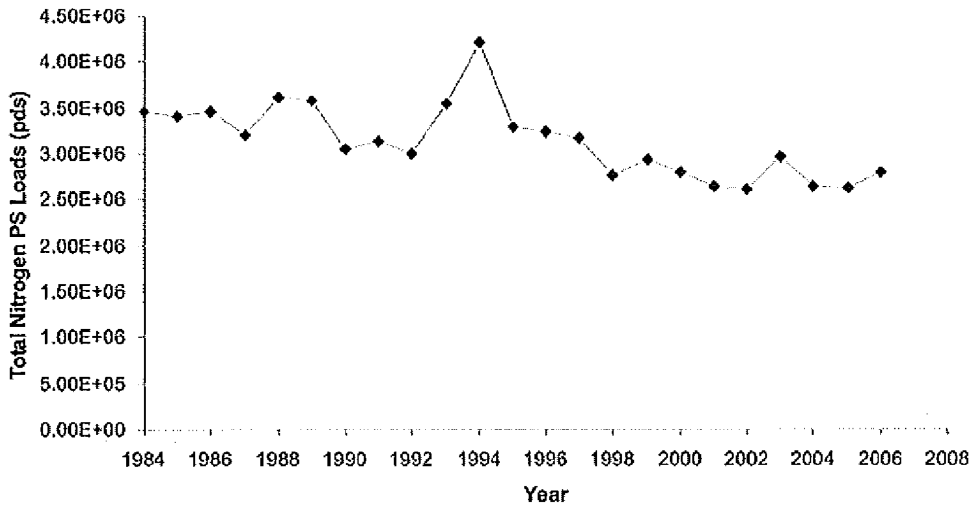


Figure 3. Location of living resource monitoring stations in the Virginia tributaries and the Lower Chesapeake Bay main stem.

A. James River Above the Fall-Line



B. James River Below the Fall-Line

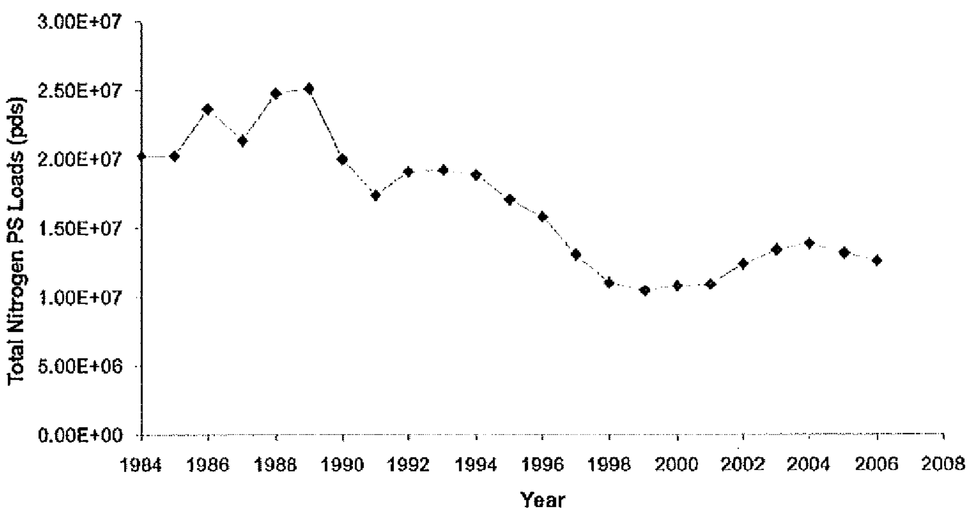
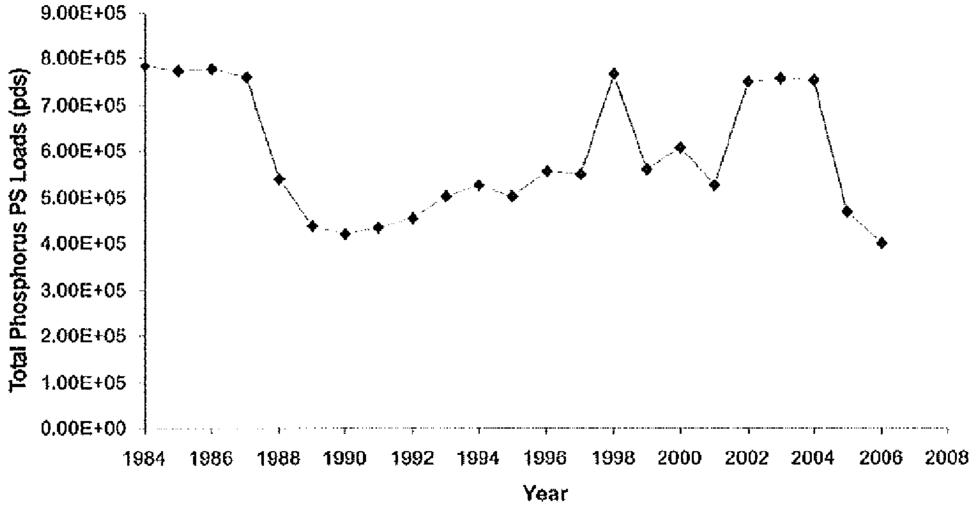


Figure 4. Long-term changes in point source total nitrogen loadings A. Above the Fall-line, and B. Below the Fall-line in the James River for 1985 through 2006. Loadings presented are from data reported to the Virginia Department of Environmental Quality directly from point source dischargers.

A. James River Above the Fall-Line



B. James River Below the Fall-Line

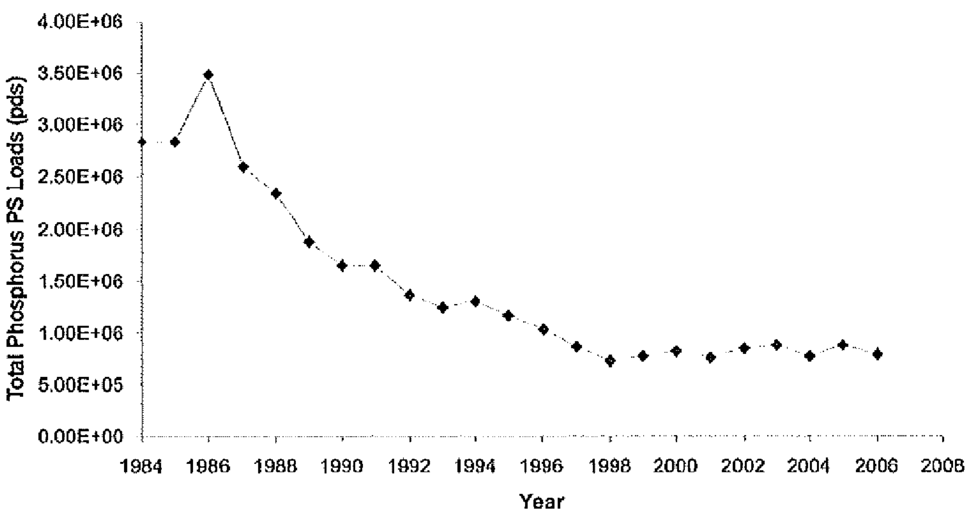
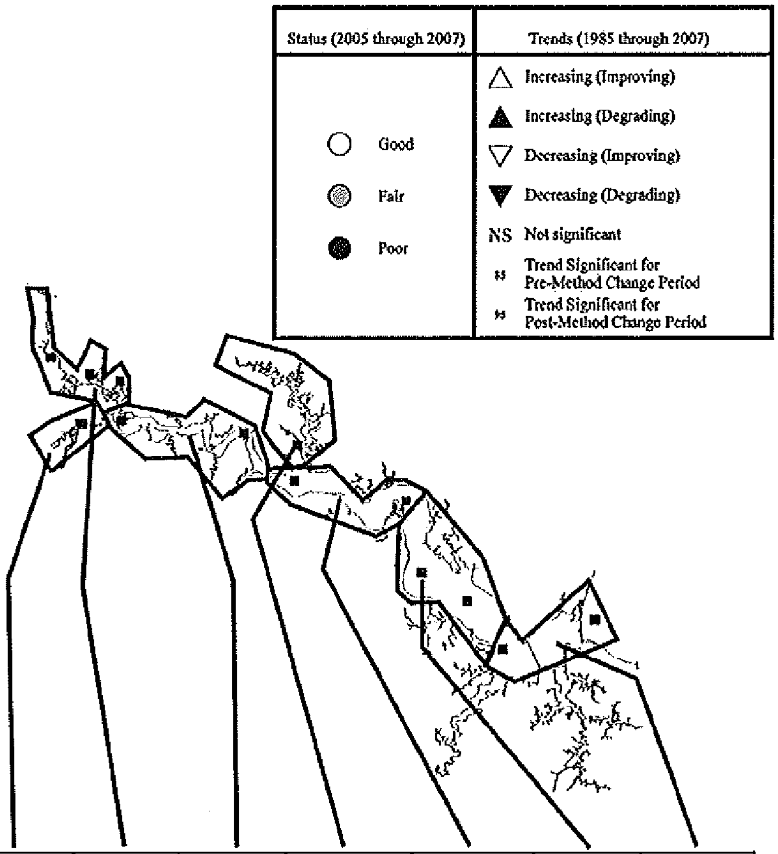
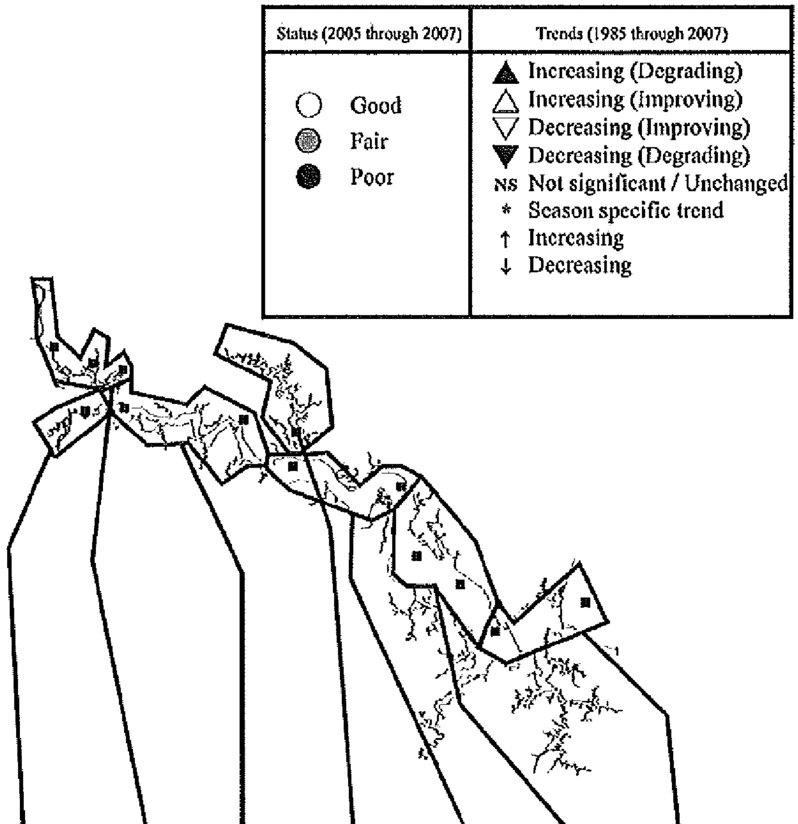


Figure 5. Long-term changes in point source total phosphorus loadings A. Above the Fall-line, and B. Below the Fall-line in the James River for 1985 through 2006. Loadings presented are from data reported to the Virginia Department of Environmental Quality directly from point source dischargers.



Parameter	Appomattox	Upper James 2	Upper James 1	Chickahominy	Middle James	Lower James	River Mouth
STN	○ NS	○ ▽▲	○ ▽	○ ▽	○ NS	○ NS	○ NS
BTN	○ NS	○ ▽▲	○ ▽	○ ▽	○ NS	○ NS	◉ NS
SDIN	○ NS	○ ▽	○ NS	○ NS	○ ▽	◉ NS	○ ▲
BDIN	○ NS	○ ▽	○ NS	○ NS	○ NS	◉ NS	○ NS
STP	○ NS	○ ▽	○ ▽	○ NS	◉ NS	◉ ▲	◉ NS
BTP	○ NS	○ ▽	○ ▲▽	○ ▽	● ▲	● NS	◉ NS
SDIP	○ ▽	○ ▽	○ NS	○ ▽	◉ NS	● ▲	◉ NS
BDIP	○ ▽	◉ ▽	◉ ▽	○ ▽	◉ NS	◉ ▲	○ NS

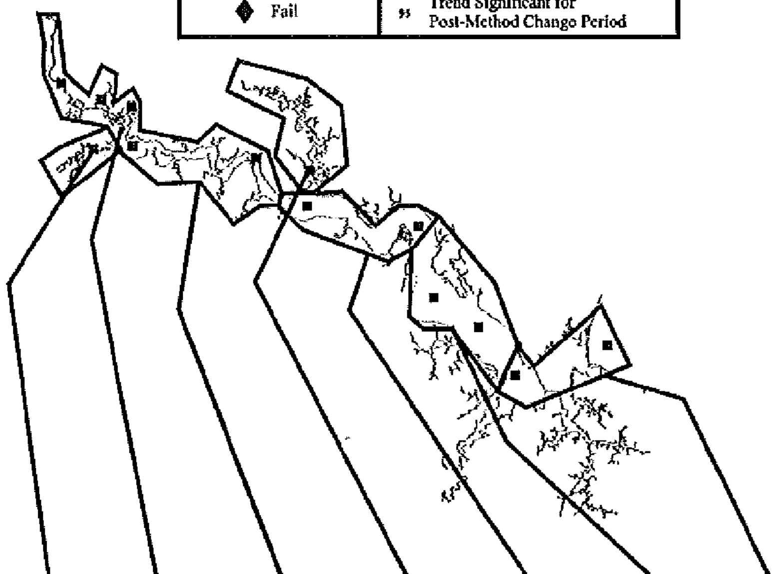
Figure 6. Map of the James River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2007. Abbreviations for each parameter are: TN=total nitrogen, DIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.



Parameter	Appomattox	Upper James 2	Upper James 1	Chickahominy	Middle James	Lower James	River Mouth
SCHLA	● NS	○ NS	○ ▽	◎ ▽	○ NS	○ NS	● ▲
STSS	● NS	◎ NS	◎ NS	● NS	● NS	● NS	◎ NS
BTSS	◎ NS	◎ ▲	◎ NS	● NS	● NS	● ▲	◎ NS
SECCHI	● NS	◎ ▼	◎ ▼	◎ ▼	● NS	● NS	● ▼
BDO	○ △	○ NS	○ NS	○ NS	○ NS	○ NS	○ △
SSALIN	NS	NS	NS	NS	NS	NS	↓
BSALIN	NS	NS	NS	NS	NS	NS	↓
SWTEMP	↑	NS	NS	NS	NS	NS	NS
BWTEMP	NS	NS	NS	NS	NS	NS	↑

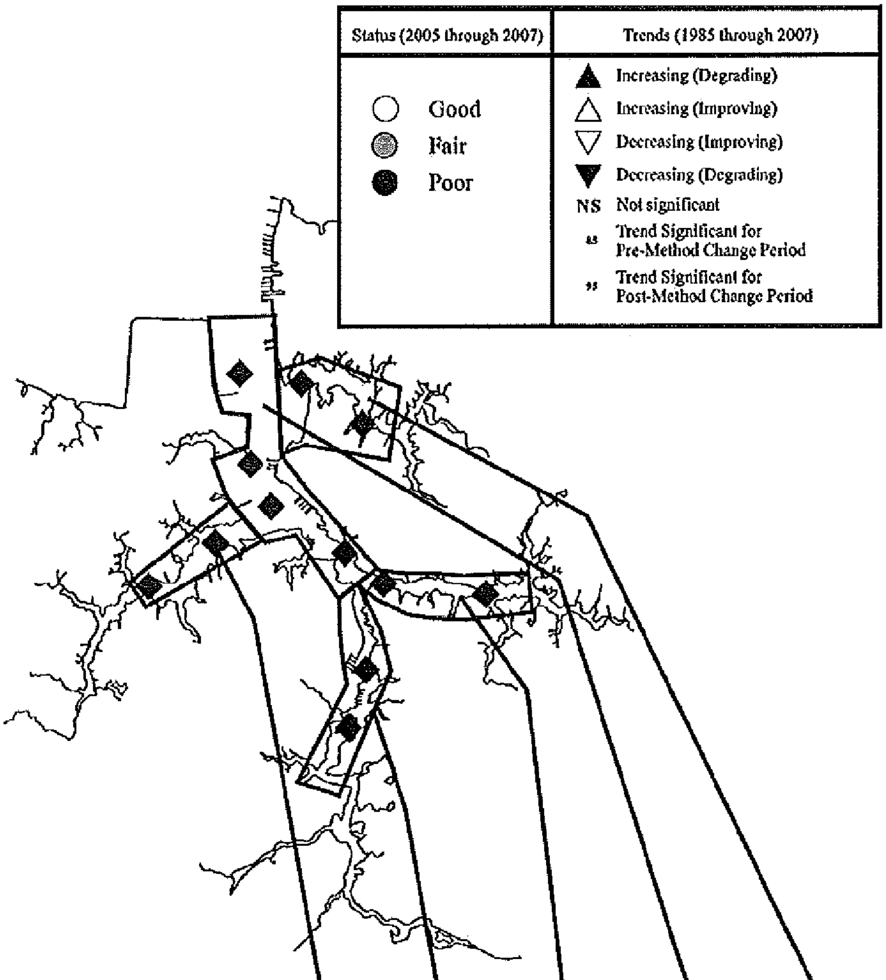
Figure 7. Map of the James River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2007. Abbreviations for each parameter are: CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=secchi depth, DO=dissolved oxygen, WTEMP=water temperature, SALIN=salinity. The prefixes S and B refer to surface and bottom measurements, respectively.

SAV Growing Season Status (2005 through 2007)	SAV Growing Season Trends (1985 through 2007)
○ Good	△ Trends Increasing (Improving)
◍ Fair	▲ Trends Increasing (Degrading)
● Poor	▽ Decreasing (Improving)
SAV Habitat Requirement (2005 through 2007)	▼ Trends Decreasing (Degrading)
◇ Pass	NS Not significant
◈ Borderline	ss Trend Significant for Pre-Method Change Period
◆ Fail	ss Trend Significant for Post-Method Change Period



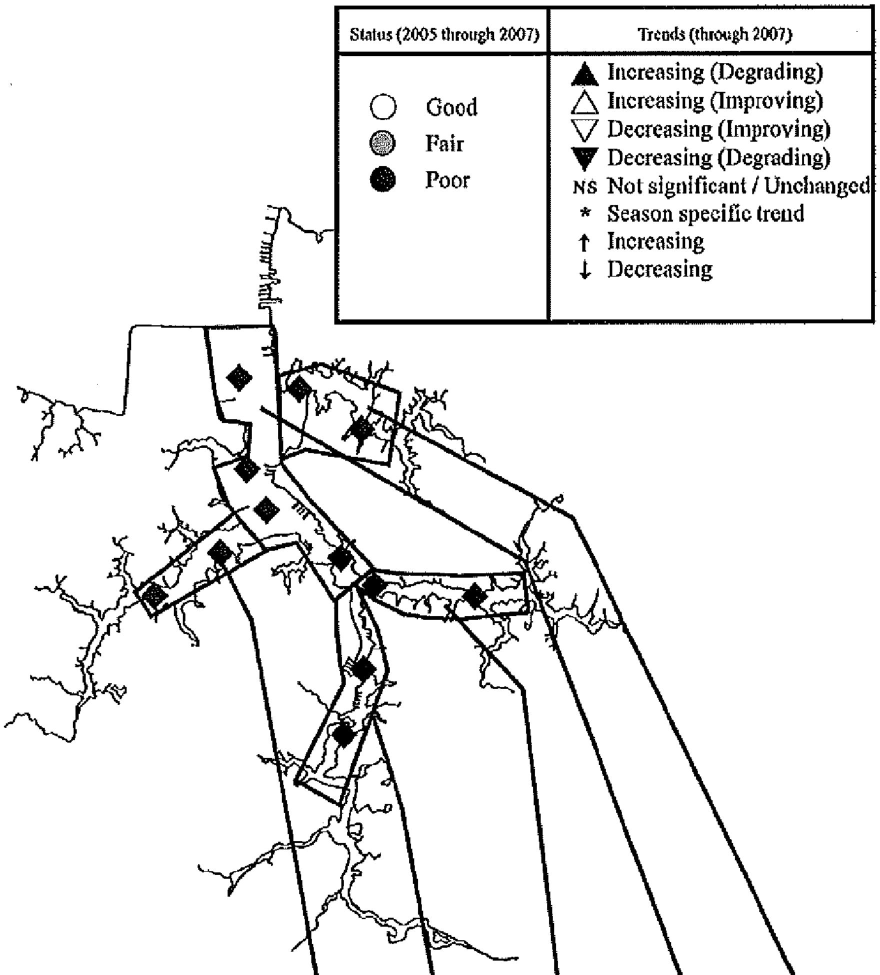
Parameter	Appomattox	Upper James 2	Upper James 1	Chickahominy	Middle James	Lower James	River Mouth
STN	○ NS	○ ▽ss/▲ss	○ ▽	○ NS	○ NS	○ NS	◍ NS
SDIN	○ NS	○ NS	○ ▽ss	○ ▲ss	○ ◇ ▽ss	◍ ◈ NS	◍ ◆ NS
STP	○ NS	○ ▽ss	○ NS	○ NS	○ NS	◍ ▲ss	● ▲ss
SDIP	○ ◇ ▽	○ ◈ ▽	○ ◈ NS	○ ◇ NS	◍ ◈ NS	● ◆ ▲	◍ ◈ NS
SCHLA	● ◈ NS	○ ◇ NS	○ ◇ ▽	◍ ◇ ▽	○ ◇ NS	○ ◇ NS	● ◇ NS
STSS	● ◆ NS	◍ ◈ NS	◍ ◈ NS	● ◆ NS	● ◆ NS	● ◈ NS	◍ ◇ NS
SECCHI	● ◆ ▼	● ◆ ▼	◍ ◈ ▼	◍ ◆ ▼	● ◆ NS	● ◆ NS	● ◈ ▼
BDO	○ NS	○ NS	○ NS	○ NS	○ NS	○ NS	○ △

Figure 8. Map of the James River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2007 for the SAV growing season. Abbreviations for each parameter are: TN=total nitrogen, SDIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus, CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=Secchi depth, DO=dissolved oxygen. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.



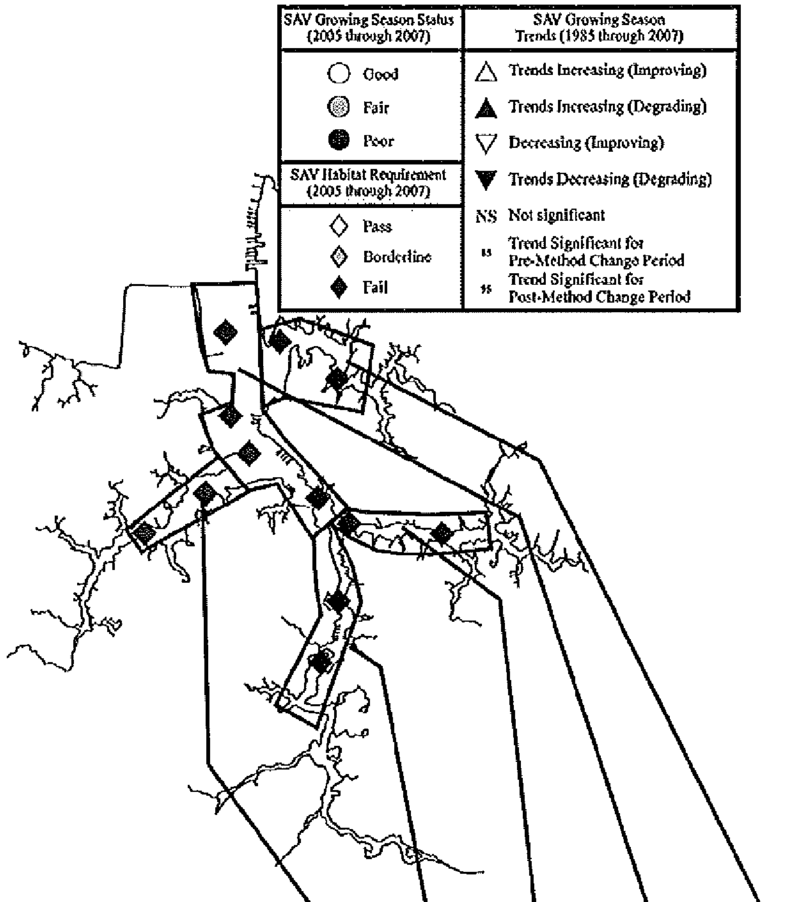
Parameter	Western Branch	Southern Branch	Eastern Branch	Elizabeth River Mainstem	Lafayette River
STN	◎ NS	● ▽	◎ NS	◎ NS	◎ NS
BTN	◎ NS	● NS	● ▽	● ▲	◎ NS
SDIN	◎ NS	● ▽	● ▽	● NS	○ NS
BDIN	◎ NS	● ▽	● ▽	● ▽	○ NS
STP	● NS	● ▽	● ▽	● NS	● NS
BTP	● NS	◎ ▽	◎ ▽	● NS	◎ NS
SDIP	● NS	● ▽	● NS	● NS	◎ NS
BDIP	◎ NS	● ▽	● ▽	● NS	◎ NS

Figure 9. Map of the Elizabeth River basin showing summaries of the status and trend analyses for each segment for the period of 1989 through 2007. Abbreviations for each parameter are: TN=total nitrogen, DIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP= dissolved inorganic phosphorus. The prefixes S and B refer to surface and bottom measurements, respectively.



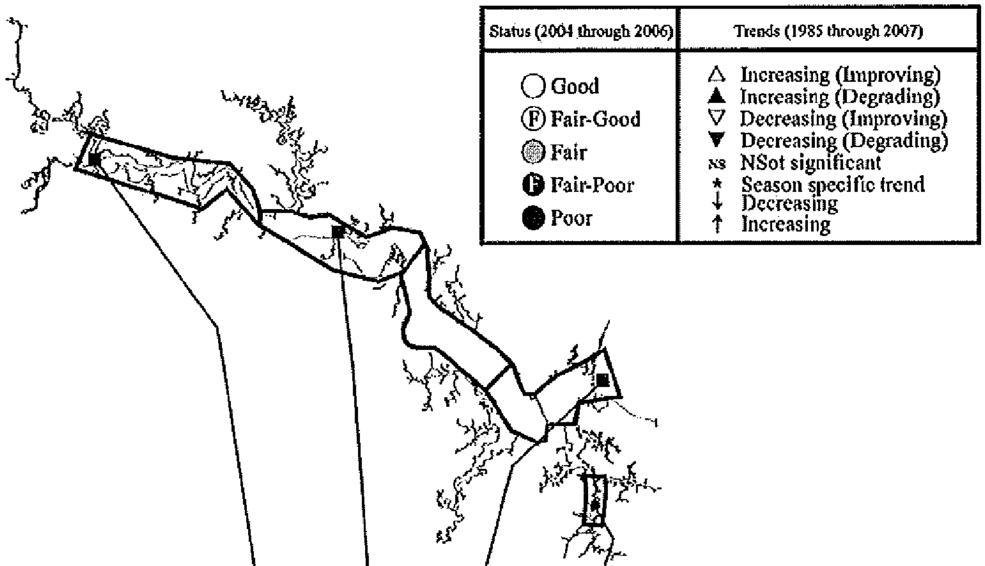
Parameter	Western Branch		Southern Branch		Eastern Branch		Elizabeth River Mainstem		Lafayette River	
SCHLA	●	NS	○	NS	◉	NS	◉	NS	●	NS
STSS	●	NS	◉	▽	◉	▽	◉	▽	●	NS
BTSS	●	NS	○	▽	○	▽	◉	▽	●	NS
SECCHI	●	NS	●	NS	●	NS	●	▼	●	NS
BDO	○	NS	◉	NS	◉	NS	○	NS	○	NS
SSALIN		NS		NS		NS		NS		NS
BSALIN		NS		NS		NS		↓		NS
SWTEMP		NS		↑		NS		↑		NS
BWTEMP		NS		↑		↑		NS		NS

Figure 10. Map of the Elizabeth River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2007. Abbreviations for each parameter are: CHLA=chlorophyll a, TSS=total suspended solids, SECCHI=secchi depth, DO=dissolved oxygen, WTEMP=water temperature, SALIN=salinity. The prefixes S and B refer to surface and bottom measurements, respectively.



Parameter	Western Branch	Southern Branch	Eastern Branch	Elizabeth River Mainstem	Lafayette River
STN	◎ NS	● ▽	◎ NS	● ▲	◎ NS
SDIN	◎ ◇ NS	● ◈ ▽	● ◆ ▽	● ◈ ▲	● ID NS
STP	● NS	● ▽	● NS	● NS	● NS
SDIP	● ◈ NS	● ◆ NS	● ◈ NS	● ◈ NS	● NS
SCHLA	◎ ◈ NS	○ ◇ NS	○ ◇ ▲	○ ◇ NS	◎ ID NS
STSS	● ◆ NS	○ ◇ ▽	◎ ◇ NS	● ◈ ▽	● ID NS
SECCHI	● ◆ NS	● ◈ NS	● ◈ NS	● ◆ ▼	● ID NS
BDO	○ NS	○ NS	○ NS	○ NS	○ NS

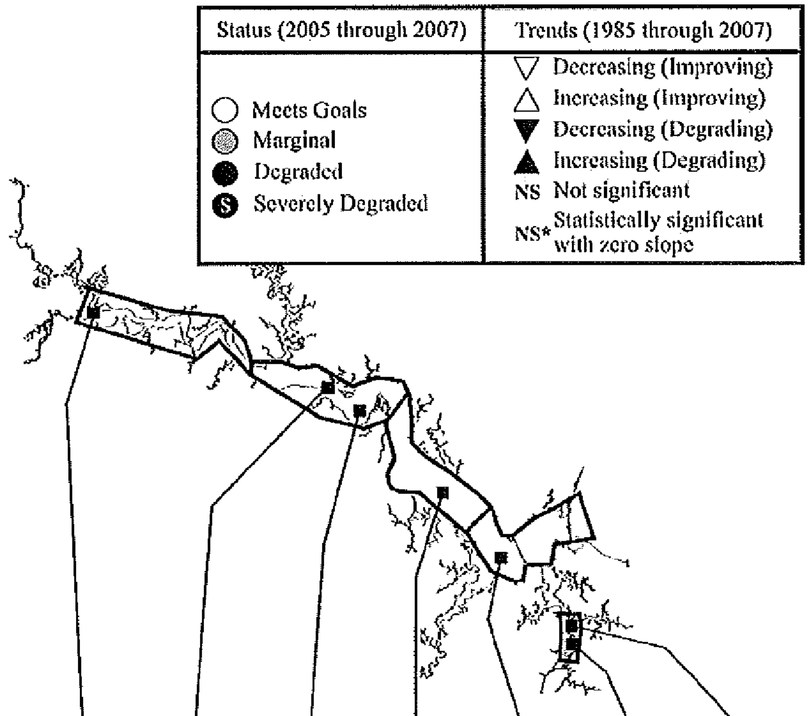
Figure 11. Map of the Elizabeth River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2007 for the SAV growing season. Abbreviations for each parameter are: TN=total nitrogen, SDIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus, CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=Secchi depth, DO=dissolved oxygen. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.



	TF5.5	RET5.2	LE5.5	SBE5
Phytoplankton IBI*	F NS	F NS	F NS	F ▼
Total Biomass	↑	↑	NS	NS
Biomass to Abundance	△	△	△	NS
Margalef Diversity Index	NS	▼	NS	NS
Productivity	▲	▽	NS	NS
Diatom Biomass	△	NS	NS	NS
Dinoflagellate Biomass	NS	NS	▲	NS
Cyanophyte Biomass	▲	NS	▲	▲
Chlorophyte Biomass	△	△	NS	NS
Picoplankton Biomass	▽	▽	NS	NS
Cryptophyte Biomass	NS	NS	NS	NS

* Status and trend results present for the Phytoplankton IBI were through 2006 due to data availability.

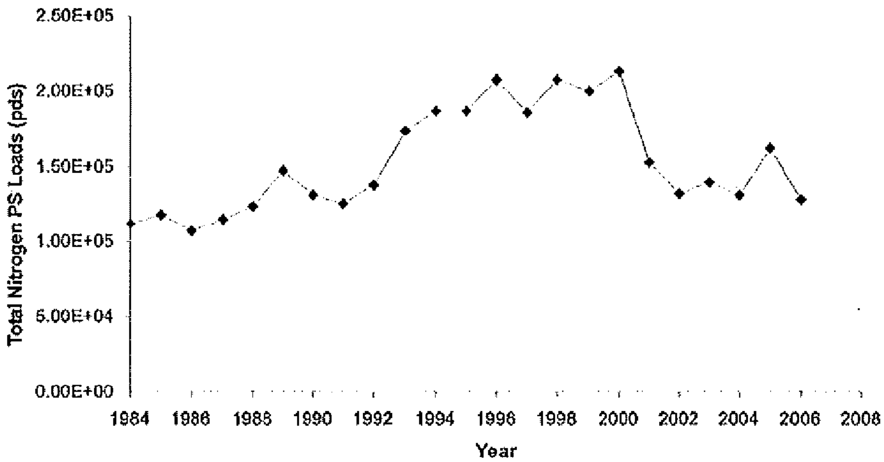
Figure 12. Map of the James River basin showing summaries of the status and trend analyses for the Phytoplankton Index of Biotic Integrity (P-IBI) and trend analyses of other phytoplankton bioindicators for each segment for the period of 1985 through 2007. Note that analytical results for the P-IBI are through 2006 due to data availability.



	TF5.5	RET5.2	LE5.1	LE5.2	LE5.4	SBE5	SBE2
Benthic IBI	● NS	◍ △	○ NS	◍ NS	○ NS	● △	● NS
Total Abundance	NS	NS	NS	△	NS	NS	△
Total Biomass	NS	NS	NS	NS	▼	NS	NS
Pollution Sensitive Species Abundance (%)	△	△	NS	△	NS	△	△
Pollution Indicative Species Abundance (%)	△	NS	NS	NS	▽	▽	▽
Pollution Sensitive Species Biomass (%)	△	△	NS	NS	▼	△	△
Pollution Indicative Species Biomass (%)	△	NS	NS	NS	NS	▽	NS
Shannon-Weiner Diversity Index	NS	△	NS	NS	▼	NS	NS

Figure 13. Map of the James River basin showing summaries of the status and trend analyses for Benthic Index of Biotic Integrity (B-IBI) and associated benthic bioindicators for each segment for the period of 1985 through 2007.

A. York River Above the Fall-Line



B. York River Below the Fall-Line

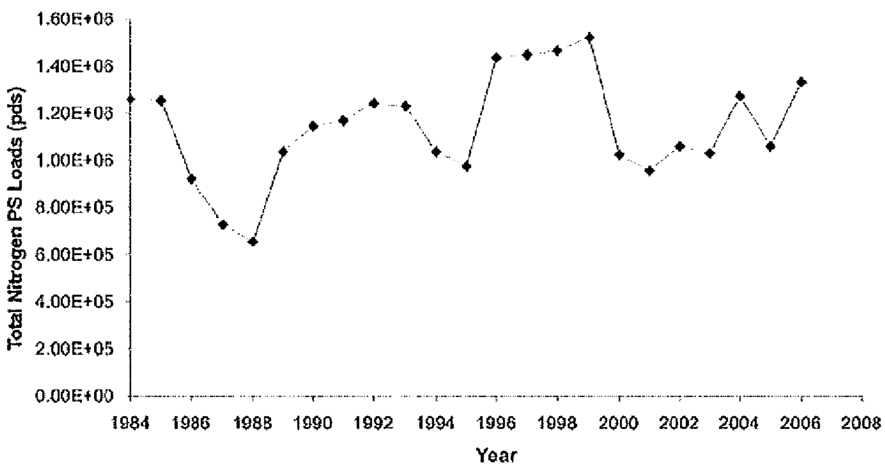
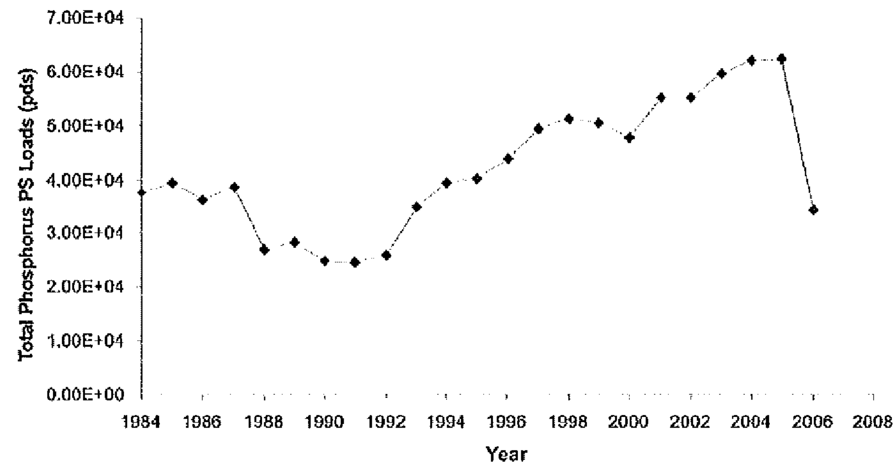


Figure 14. Long-term changes in point source total nitrogen loadings in the York River A)Above the Fall-Line and B) Below the Fall-line for 1985 through 2006. Loadings presented are from data reported to the Virginia Department of Environmental Quality directly from point source dischargers.

A. York River Above the Fall-Line



B. York River Below the Fall-Line

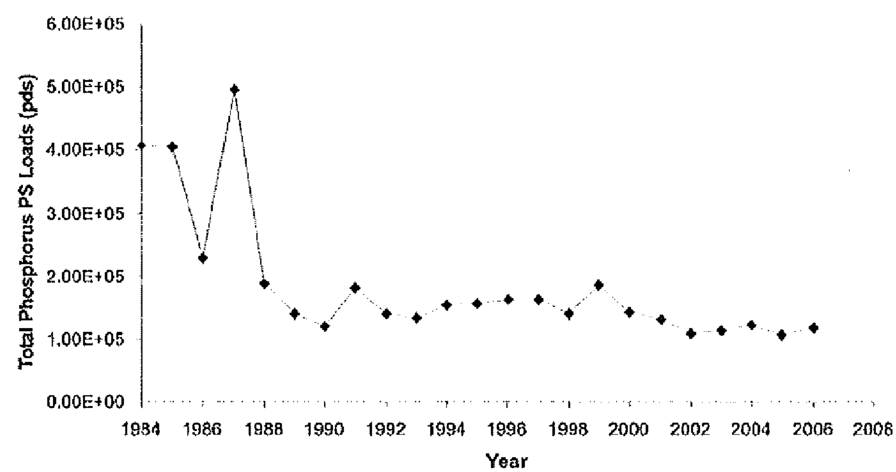
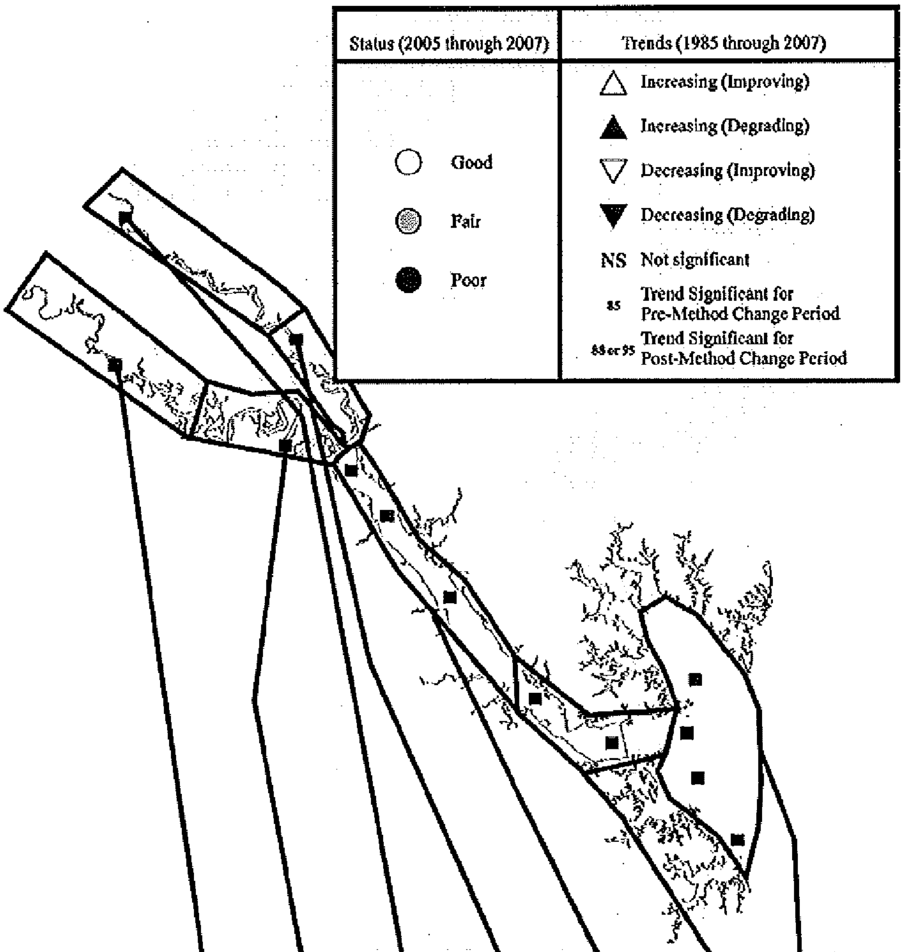
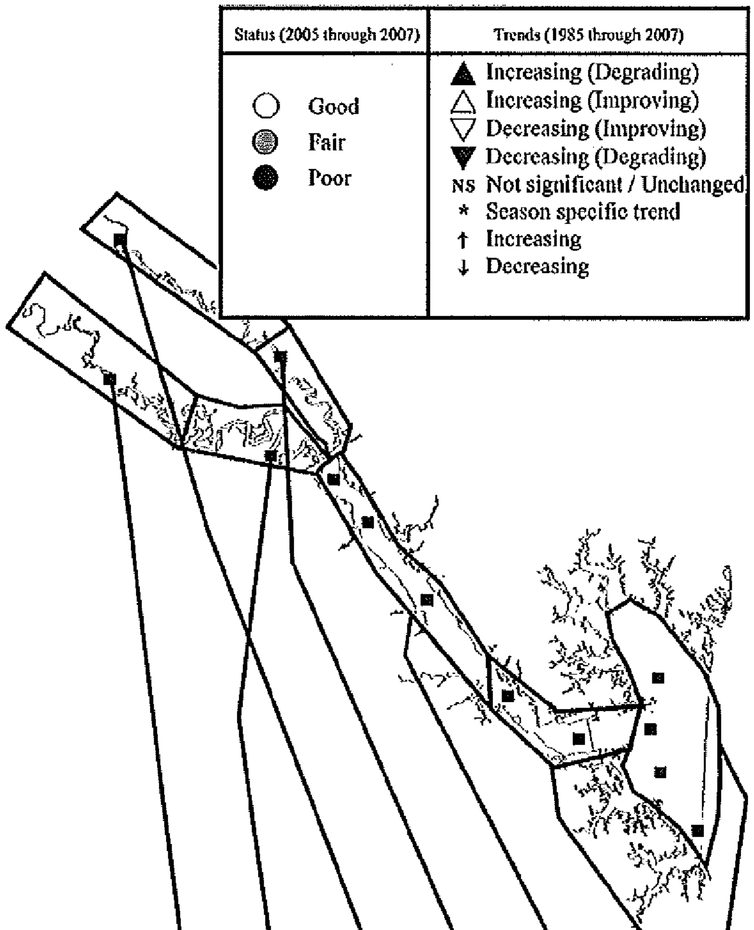


Figure 15. Long-term changes in point source total phosphorus loadings in the A) Above the Fall-Line B) Below the Fall-line for 1985 through 2006. Loadings presented are from data reported to the Virginia Department of Environmental Quality directly from point source dischargers.



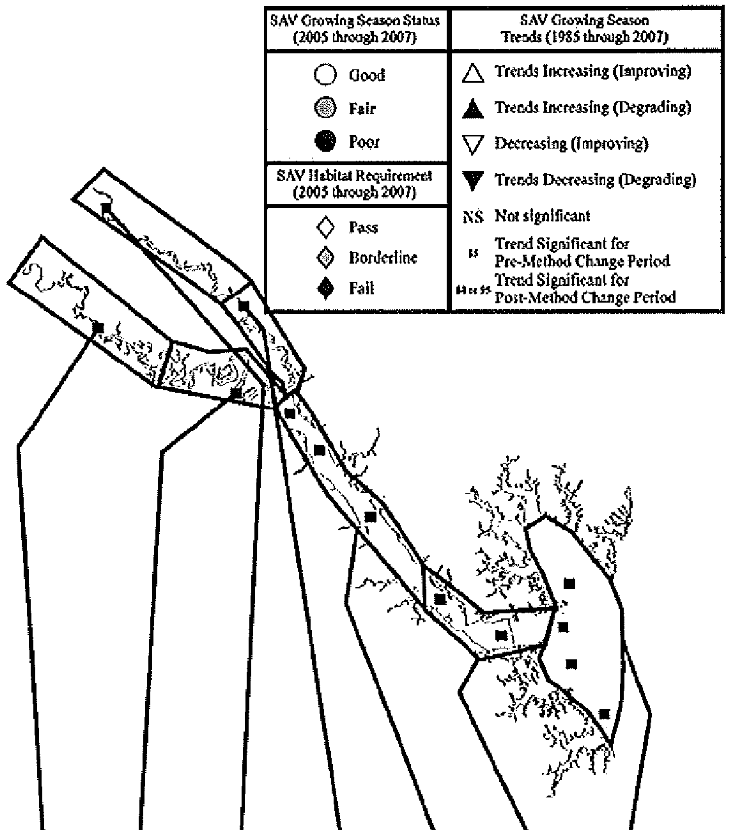
Parameter	Upper Pamunkey		Lower Pamunkey		Upper Mattaponi		Lower Mattaponi		Middle York		Lower York		Mobjack Bay	
STN	○	▲	○	NS	○	NS	○	▲	○	NS	○	▲	◍	▽
BTN	○	NS	◍	▲	○	NS	○	NS	◍	▲	◍	▲	◍	▽
SDIN	○	▲ 85	○	NS	○	▲ 85	○	NS	○	NS	○	NS	○	NS
BDIN	○	NS	○	NS	○	▲	○	NS	○	NS	○	NS	○	NS
STP	○	▲	◍	▲ 85	○	▲ 85	◍	NS	●	▲ 85	◍	▲	○	▽
BTP	○	▲	●	▲	○	NS	●	NS	●	▲	◍	▲ 85	○	▽
SDIP	○	▽ 95	◍	NS	○	▽ 95	◍	NS	●	▲	◍	NS	○	NS
BDIP	○	▽ 95	◍	NS	○	▽ 95	◍	NS	◍	▲	◍	NS	○	NS

Figure 16. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period of 1985 to 2007. Abbreviations for each parameter are: TN=total nitrogen, DIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.



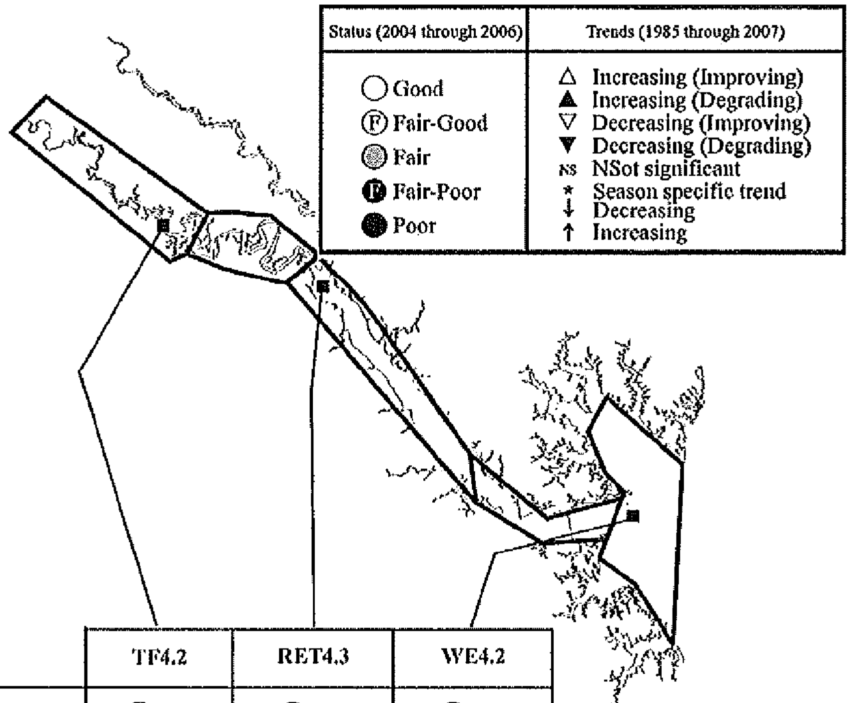
Parameter	Upper Pamunkey	Lower Pamunkey	Upper Mattaponi	Lower Mattaponi	Middle York	Lower York	Mobjack Bay
SCHLA	○ NS	○ NS	○ NS	○ NS	◎ NS	◎ ▲	◎ NS
STSS	◎ NS	● ▽	○ NS	● NS	● NS	◎ NS	◎ ▽
BTSS	○ NS	● NS	○ NS	● NS	● NS	● NS	● ▽
SECCHI	◎ ▼	● NS	○ ▼	● NS	● NS	● ▼	● ▼
BDO	○ △	◎ NS	○ NS	○ NS	◎ NS	◎ NS	○ △
SSALIN	NS	↑	NS	↑	NS	↓	↓
BSALIN	NS	NS	NS	↑	NS	NS	↓
SWTEMP	NS	NS	↑	NS	NS	NS	NS
BWTEMP	NS	NS	NS	NS	NS	NS	NS

Figure 17. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period of 1985 to 2007. Abbreviations for each parameter are: CHLA=chlorophyll a, TSS=total suspended solids, SECCHI=secchi depth, DO=dissolved oxygen, WTEMP=water temperature, SALIN=salinity. The prefixes S and B refer to surface and bottom measurements, respectively.



Parameter	Upper Pamunkey	Lower Pamunkey	Upper Mattaponi	Lower Mattaponi	Middle York	Lower York	Mobjack Bay
STN	○ NS	○ ▲	○ NS	○ ▲	○ NS	◎ ▲	◎ ▽
SDIN	○ NS	○ ◇ NS	○ NS	○ ◈ NS	○ ◇ NS	○ ◇ NS	○ ◇ NS
STP	○ NS	● ▽▲	○ NS	◎ ▲	● ▲	◎ ▲	◎ ▽
SDIP	○ ◇ ▽	◎ ◈ NS	○ ◇ ▽	◎ ◈ NS	● ◆ ▲	◎ ◇ NS	○ ◇ NS
SCHLA	○ ◇ NS	○ ◇ NS	○ ◇ NS	○ ◇ NS	○ ◇ NS	◎ ◇ NS	◎ ◇ NS
STSS	◎ ◈ NS	● ◆ ▽	○ ◇ NS	● ◆ NS	● ◆ NS	◎ ◇ NS	◎ ◇ ▽
SECCHI	◎ ◈ NS	● ◆ NS	○ ◇ NS	● ◆ NS	● ◆ NS	● ◈ ▼	● ◆ ▼
BDO	○ △	○ NS	○ NS	○ NS	○ NS	○ △	○ △

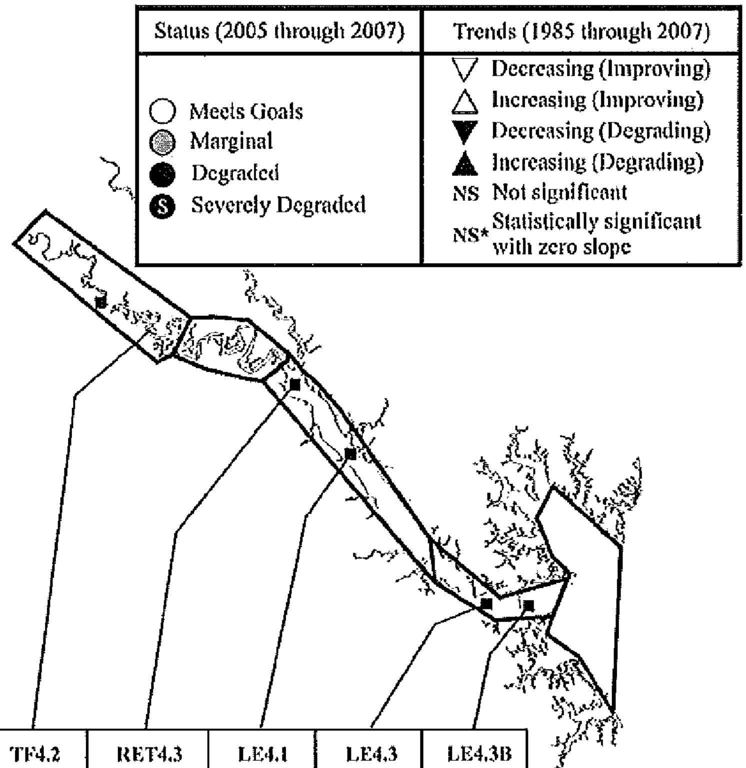
Figure 18. Map of the York River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2007 for the SAV growing season. Abbreviations for each parameter are: TN=total nitrogen, SDIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus, CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=Secchi depth, DO=dissolved oxygen. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.



	TF4.2	RET4.3	WE4.2
Phytoplankton IBI*	◍ NS	● NS	◍ NS
Total Biomass	NS	↑	NS
Biomass to Abundance	△	△	NS
Margalef Diversity Index	NS	NS	▼
Productivity	NS	▲	▲
Diatom Biomass	NS	NS	NS
Dinoflagellate Biomass	NS	NS	NS
Cyanophyte Biomass	▲	▲	▲
Chlorophyte Biomass	△	△	NS
Picoplankton Biomass	NS	NS	NS
Cryptophyte Biomass	NS	NS	↓

* Status and trend results present for the Phytoplankton IBI were through 2006 due to data availability.

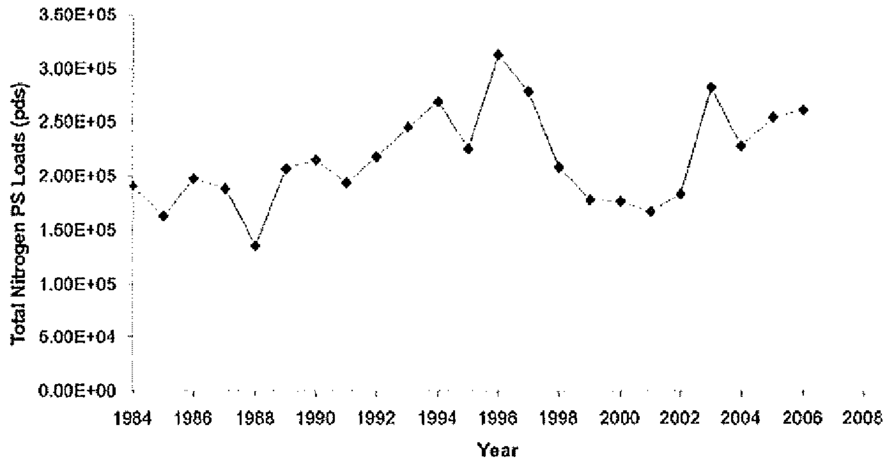
Figure 19. Map of the York River basin showing summaries of the status and trend analyses for the Phytoplankton Index of Biotic Integrity (P-IBI) and trend analyses of other phytoplankton bioindicators for each segment for the period of 1985 through 2007. Note that analytical results for the P-IBI are through 2006 due to data availability.



	TF4.2	RET4.3	LE4.1	LE4.3	LE4.3B
Benthic IBI	● NS	● NS	Ⓢ NS	○ NS	● △
Total Abundance	△	△	NS	NS	NS
Total Biomass	NS	NS	NS	NS	NS
Pollution Sensitive Species Abundance (%)	NS	NS	NS	NS	NS
Pollution Indicative Species Abundance (%)	NS	NS	NS	NS	▽
Pollution Sensitive Species Biomass (%)	NS	NS	▼	NS	NS
Pollution Indicative Species Biomass (%)	NS	NS	▲	NS	NS
Shannon-Weiner Diversity Index	△	NS	▼	NS	NS

Figure 20. Map of the York River basin showing summaries of the status and trend analyses for Benthic Index of Biotic Integrity (B-IBI) and associated benthic bioindicators for each segment for the period of 1985 through 2007.

A. Rappahannock River Above the Fall-Line



B. Rappahannock River Below the Fall-Line

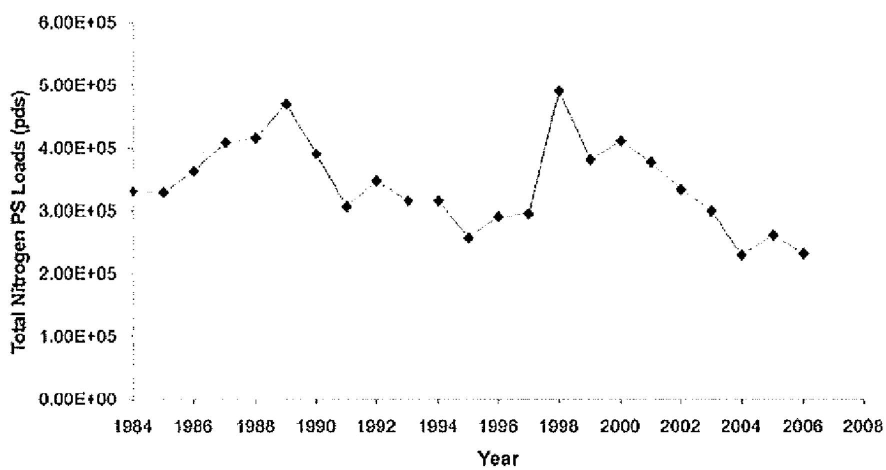
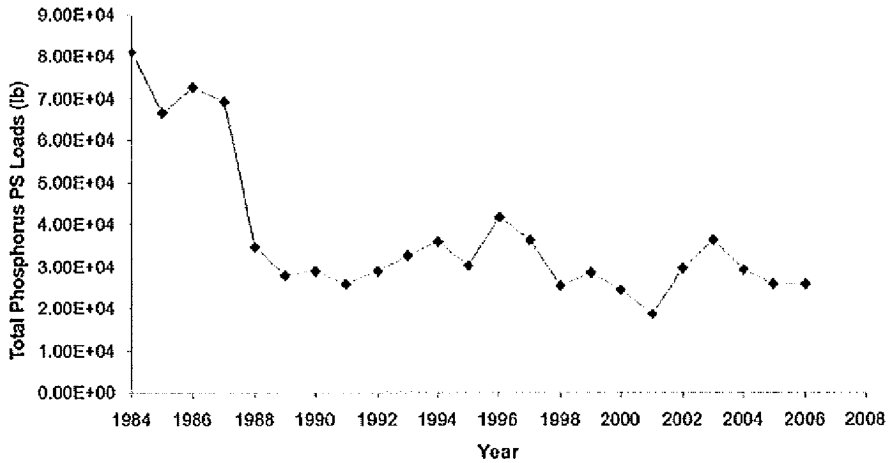


Figure 21. Long-term changes in point source total nitrogen loadings A. Above the Fall-line, and B. Below the Fall-line in the Rappahannock River for 1985 through 2006. Loadings presented are from data reported to the Virginia Department of Environmental Quality directly from point source dischargers.

A. Rappahannock River Above the Fall-Line



B. Rappahannock River Below the Fall-Line

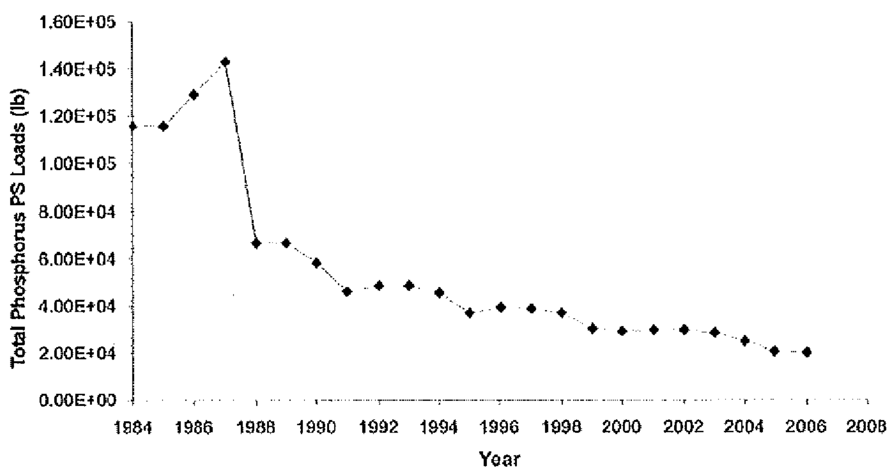
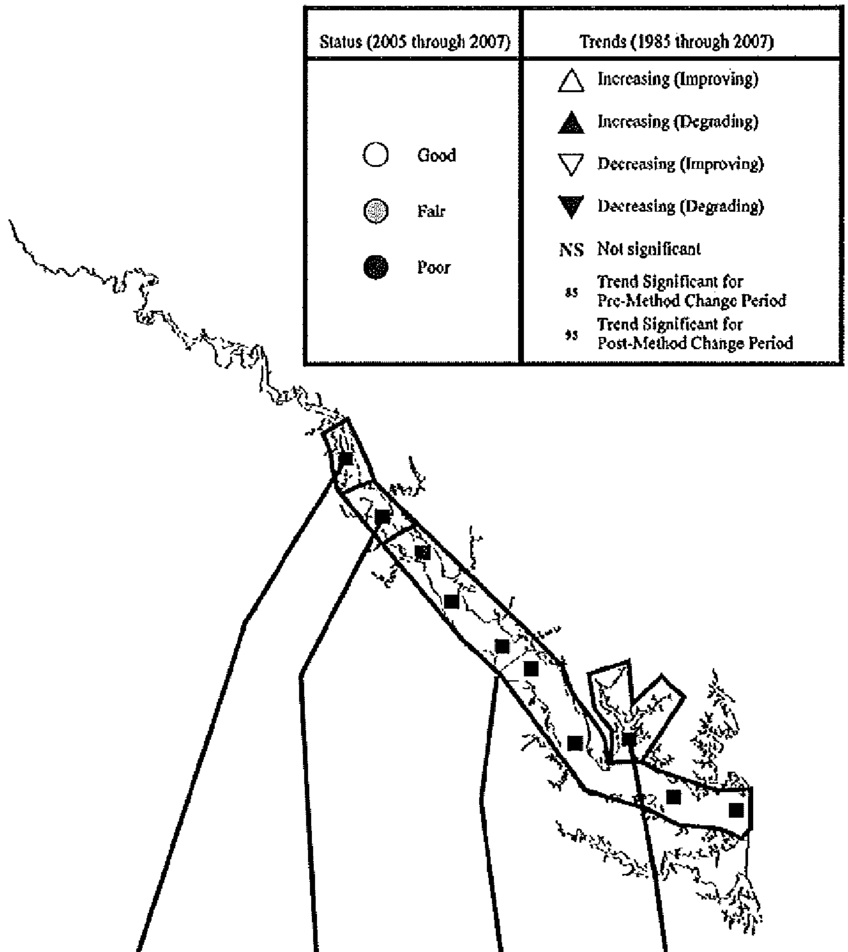
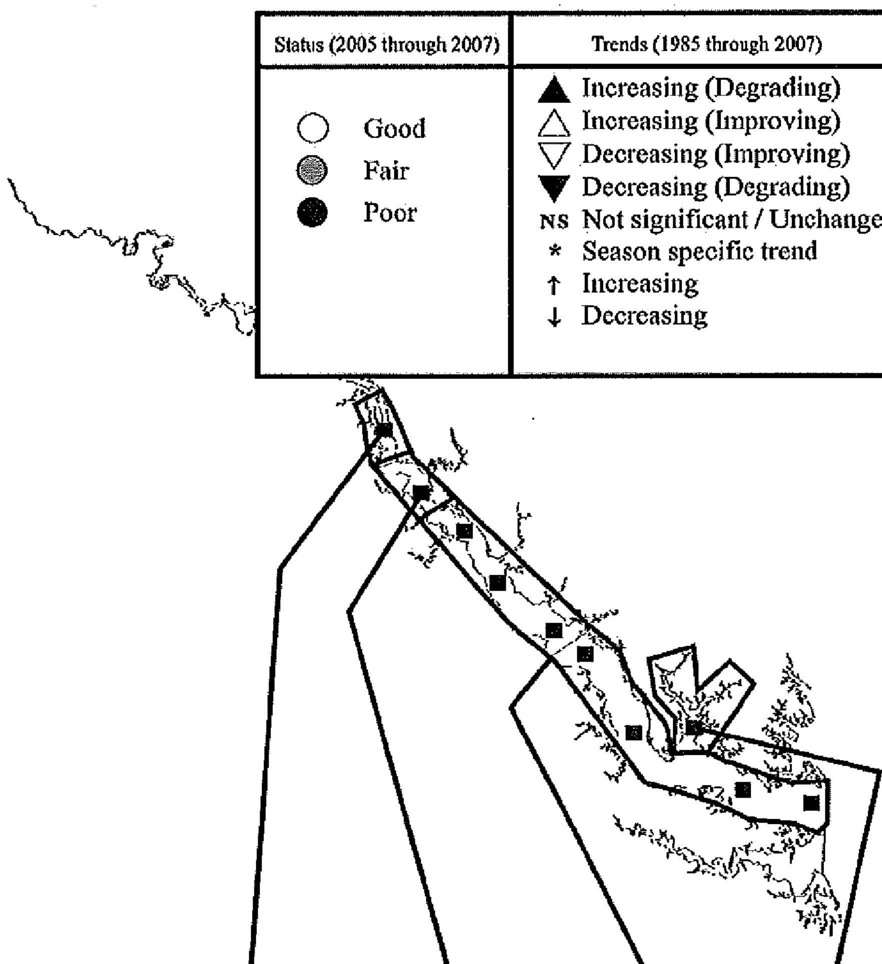


Figure 22. Long-term changes in point source total phosphorus loadings A. Above the Fall-line, and B. Below the Fall-line in the Rappahannock River for 1985 through 2006. Loadings presented are from data reported to the Virginia Department of Environmental Quality directly from point source dischargers.



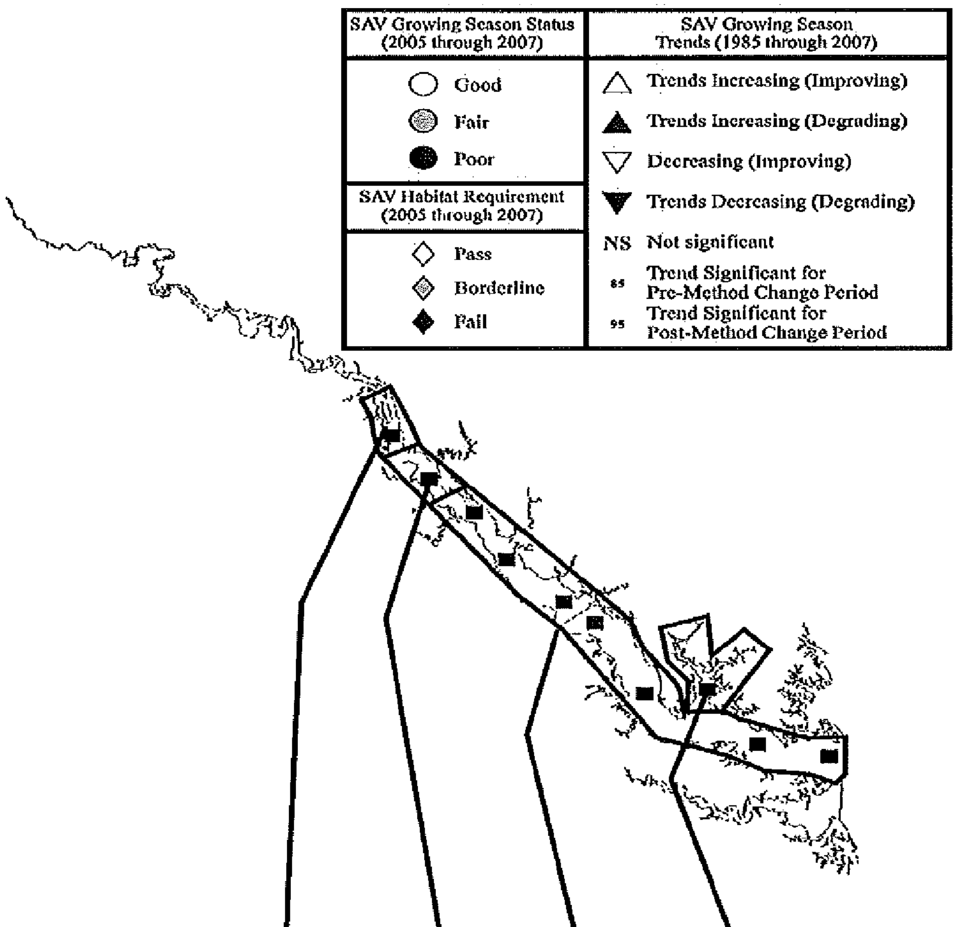
Parameter	Upper Rappahannock	Middle Rappahannock	Lower Rappahannock	Corottoman River
STN	○ NS	○ NS	○ NS	○ NS
BTN	○ NS	○ ▲	○ NS	○ NS
SDIN	○ NS	○ NS	○ ▽85	○ ▽
BDIN	○ NS	○ NS	○ NS	○ NS
STP	○ NS	◎ NS	○ ▲85	○ ▲
BTP	○ NS	◎ ▲	○ ▲85	○ ▲85
SDIP	○ ▽95	○ NS	○ NS	○ NS
BDIP	○ ▽95	○ ▽95	○ NS	○ NS

Figure 23. Map of the Rappahannock River basin showing summaries of the status and trend analyses for each segment for the period 1985 through 2007. Abbreviations for each parameter are: TN=total nitrogen, DIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.



Parameter	Upper Rappahannock	Middle Rappahannock	Lower Rappahannock	Corottoman River
SCHLA	○ NS	◍ ▲	◍ ▲	◍ NS
STSS	● NS	● NS	◍ NS	○ NS
BTSS	◍ NS	● NS	◍ NS	○ NS
SECCHI	● NS	● NS	● ▼	◍ ▼
BDO	○ NS	○ NS	◍ NS	◍ NS
SSALIN	NS	NS	↓	↓
BSALIN	NS	NS	↓	↓
SWTEMP	NS	NS	NS	NS
BWTEMP	NS	NS	NS	NS

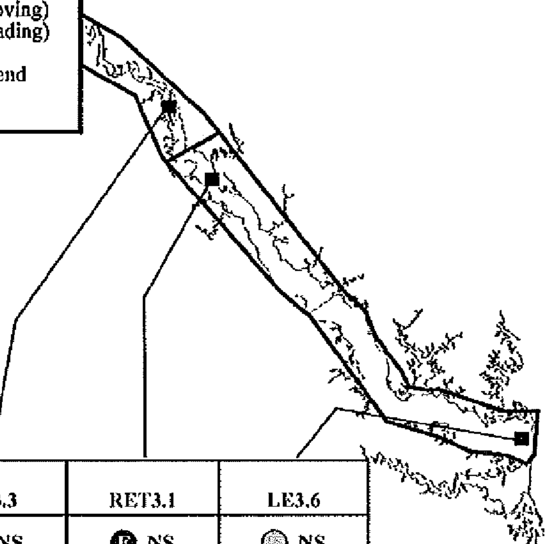
Figure 24. Map of the Rappahannock River basin showing summaries of the status and trend analyses for each segment for the period 1985 through 2007. Abbreviations for each parameter are: CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=secchi depth, DO=dissolved oxygen, WTEMP=water temperature, SALIN=salinity. The prefixes S and B refer to surface and bottom measurements, respectively.



Parameter	Upper Rappahannock	Middle Rappahannock	Lower Rappahannock	Corottoman River
STN	○ NS	○ NS	○ NS	○ NS
SDIN	○ NS	○ NS	○ ◇ ▽85	○ ◇ ▽
STP	○ NS	○ NS	◍ ▲85	◍ NS
SDIP	○ ◇ NS	○ ◇ NS	○ ◇ NS	◍ ◇ NS
SCHLA	○ ◈ NS	● ◈ ▲	◍ ◇ ▲	◍ ◇ NS
STSS	● ◆ NS	● ◆ NS	◍ ◇ NS	○ ◇ NS
SECCHI	● ◆ NS	● ◆ NS	● ◈ ▼	◍ ◇ ▼
BDO	○ NS	○ NS	○ NS	○ NS

Figure 25. Map of the Rappahannock River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2007 for the SAV growing season. Abbreviations for each parameter are: TN=total nitrogen, SDIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus, CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=Secchi depth, DO=dissolved oxygen. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the first symbol represents the pre-method change result while the second symbol is the post method change result.

Status (2004 through 2006)	Trends (1985 through 2007)
○ Good Ⓕ Fair-Good ◍ Fair 🅕 Fair-Poor ● Poor	△ Increasing (Improving) ▲ Increasing (Degrading) ▽ Decreasing (Improving) ▼ Decreasing (Degrading) NS NSot significant * Season specific trend ↓ Decreasing ↑ Increasing

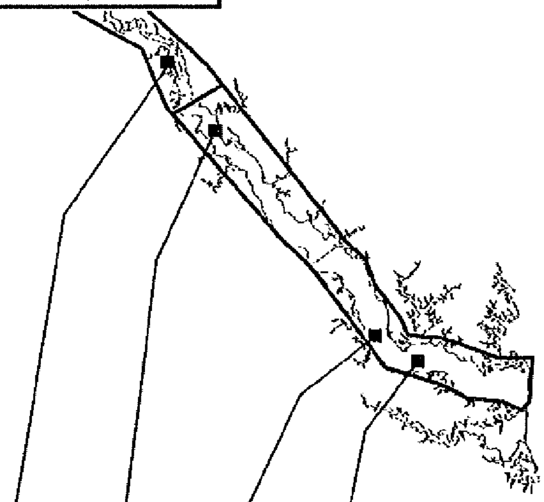


	TF3.3	RET3.1	LE3.6
Phytoplankton IBI*	● NS	🅕 NS	◍ NS
Total Biomass	↑	↑	NS
Biomass to Abundance	△	△	△
Margalef Diversity Index	NS	NS	▼
Productivity	▲	▲	▲
Diatom Biomass	△	△	NS
Dinoflagellate Biomass	▲	NS	▲
Cyanophyte Biomass	▲	▲	▲
Chlorophyte Biomass	△	△	NS
Picoplankton Biomass	NS	NS	▽
Cryptophyte Biomass	NS	NS	↓

* Status and trend results present for the Phytoplankton IBI were through 2006 due to data availability.

Figure 26. Map of the Rappahannock River basin showing summaries of the status and trend analyses for the Phytoplankton Index of Biotic Integrity (P-IBI) and trend analyses of other phytoplankton bioindicators for each segment for the period of 1985 through 2007. Note that analytical results for the P-IBI are through 2006 due to data availability.

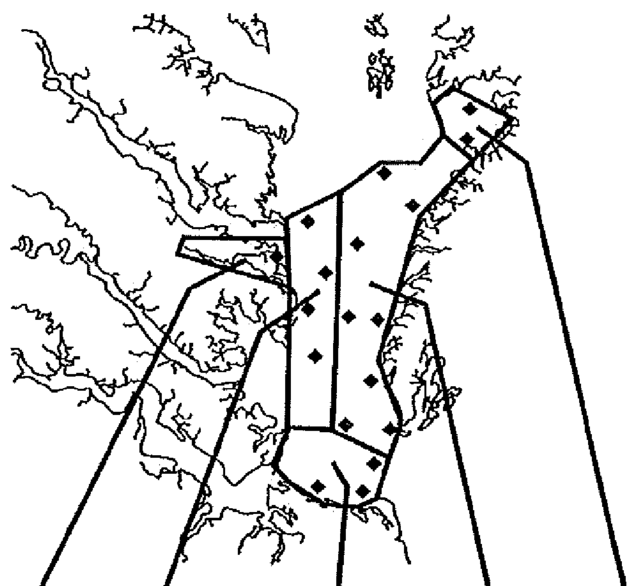
Status (2005 through 2007)	Trends (1985 through 2007)
○ Meets Goals ◍ Marginal ● Degraded Ⓢ Severely Degraded	▽ Decreasing (Improving) △ Increasing (Improving) ▼ Decreasing (Degrading) ▲ Increasing (Degrading) NS Not significant NS* Statistically significant with zero slope



	TF3.3	RET3.1	LE3.2	LE3.4
Benthic IBI	○ NS	◍ ▼	Ⓢ NS	Ⓢ NS
Total Abundance	NS	NS	NS	NS
Total Biomass	▼	▼	NS	NS
Pollution Sensitive Species Abundance (%)	NS	▼	NS	NS
Pollution Indicative Species Abundance (%)	NS	NS	NS	NS
Pollution Sensitive Species Biomass (%)	▼	▼	NS	NS
Pollution Indicative Species Biomass (%)	NS	NS	NS	NS
Shannon-Weiner Diversity Index	NS	NS	NS	NS

Figure 27. Map of the Rappahannock River basin showing summaries of the status and trend analyses for Benthic Index of Biotic Integrity (B-IBI) and associated benthic bioindicators for each segment for the period of 1985 through 2007.

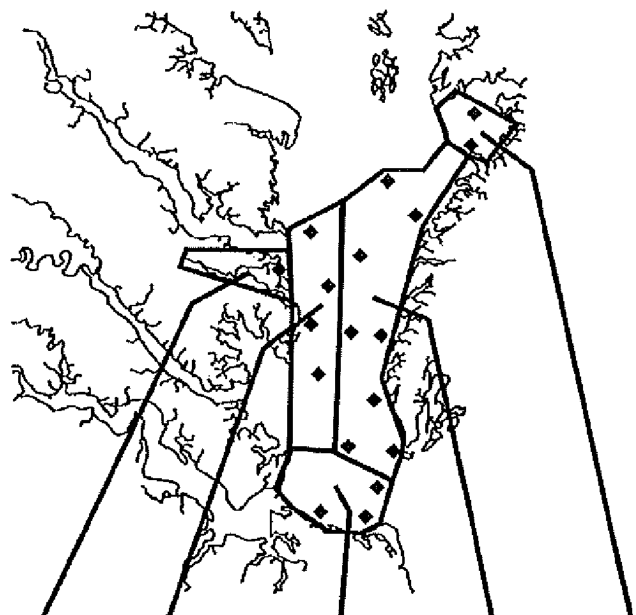
Status (2005 through 2007)	Trends (1985 through 2007)
○ Good ◉ Fair ● Poor	▲ Increasing (Degrading) △ Increasing (Improving) ▽ Decreasing (Improving) ▼ Decreasing (Degrading) NS Not significant ss Trend Significant for Pre-Method Change Period ss Trend Significant for Post-Method Change Period



Parameter	Piankatank River		Lower Western Mainstem		Lower Mainstem		Lower Eastern Mainstem		Pocomoke Sound	
STN	○	▽	○	▽	○	NS	○	▽	○	▽
BTN	○	▽	○	▽	○	NS	○	▽	◉	▽
SDIN	○	NS	○	NS	○	▲	○	NS	○	▽
BDIN	○	NS	◉	NS	○	▲▽	○	NS	○	▽
STP	○	▽	○	▽	○	▽	○	▽	○	▽
BTP	○	▽	○	NS	○	▽	○	▽	○	▽
SDIP	○	NS	○	NS	○	NS	○	NS	○	NS
BDIP	○	NS	○	NS	○	NS	○	NS	○	▽

Figure 28. Map of the Virginia Chesapeake Bay Mainstem showing summaries of the status and trend analyses for each segment for the period of 1985 through 2007. Abbreviations for each parameter are: TN=total nitrogen, DIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.

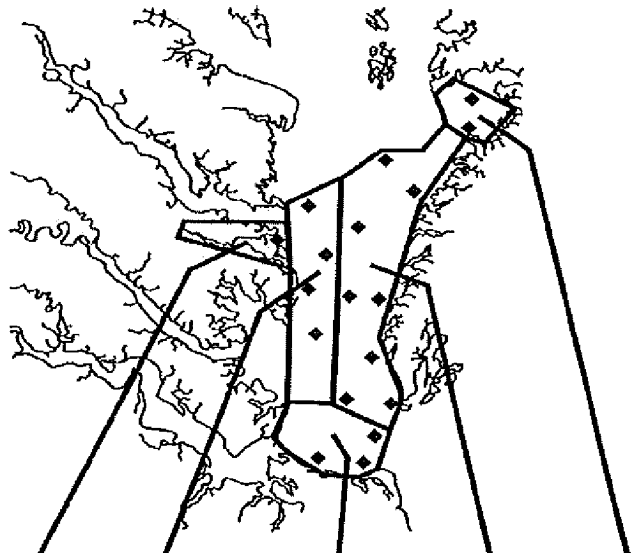
Status (2005 through 2007)	Trends (1985 through 2007)
○ Good ◍ Fair ● Poor	▲ Increasing (Degrading) △ Increasing (Improving) ▽ Decreasing (Improving) ▼ Decreasing (Degrading) NS Not significant / Unchanged * Season specific trend ↑ Increasing ↓ Decreasing



Parameter	Piankatank River	Lower Western Mainstem	Lower Mainstem	Lower Eastern Mainstem	Pocomoke Sound
SCHLA	◍ NS	◍ NS	○ NS	◍ NS	● NS
STSS	○ ▽	○ ▽	○ NS	○ ▲	● ▽
BTSS	○ ▽	○ ▽	○ NS	◍ ▲	◍ ▽
SECCHI	● ▼	◍ ▼	● ▼	◍ ▼	● ▼
BDISOXY	○ NS	◍ △	○ NS	○ NS	○ NS
SSALINITY	↓	↓	↓	↓	↓
BSALINITY	↓	↓	↓	↓	↓
SWTEMP	NS	NS	NS	NS	NS
BWTEMP	NS	NS	NS	NS	NS

Figure 29. Map of the James River basin showing summaries of the status and trend analyses for each segment for the period of 1985 through 2007. Abbreviations for each parameter are: CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=secchi depth, DO=dissolved oxygen, WTEMP=water temperature, SALIN=salinity. The prefixes S and B refer to surface and bottom measurements, respectively.

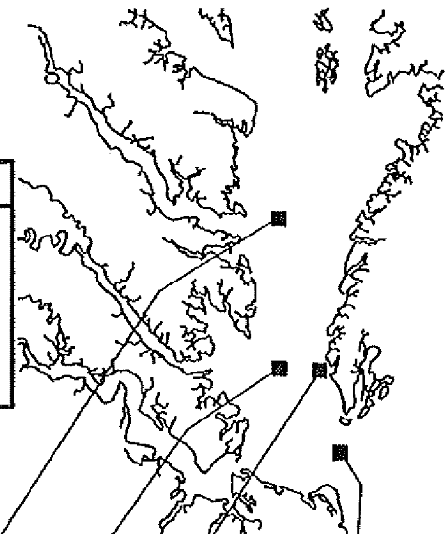
SAV Growing Season Status (2005 through 2007)	SAV Growing Season Trends (1985 through 2007)
○ Good	△ Trends Increasing (Improving)
◍ Fair	▲ Trends Increasing (Degrading)
● Poor	▽ Decreasing (Improving)
SAV Habitat Requirement (2005 through 2007)	▼ Trends Decreasing (Degrading)
◇ Pass	NS Not significant
◈ Borderline	85 Trend Significant for Pre-Method Change Period
◆ Fail	88 or 95 Trend Significant for Post-Method Change Period



Parameter	Piankatank River	Lower Western Mainstem	Lower Mainstem	Lower Eastern Mainstem	Pocomoke Sound
STN	○ ▽	○ ▽	○ NS	○ ▽	◍ ▽
SDIN	○◇ NS	○◇ NS	○◇ ▲	○◇ NS	○◇ ▽
STP	○ NS	○ ▽	○ ▽	○ ▽	○ ▽
SDIP	○◇ NS	○◇ NS	○◇ NS	○◇ NS	○◇ NS
SCHLA	◍◇ NS	◍◇ NS	○◇ NS	◍◇ NS	●◇ NS
STSS	○◇ ▽	○◇ NS	○◇ NS	○◇ NS	●◈ NS
SECCHI	●◈ ▼	◍◇ ▼	●◇ ▼	◍◇ ▼	●◆ ▼
BDISOXY	○ △	○ △	○ △	○ △	○ NS

Figure 30. Map of the Virginia Chesapeake Bay Mainstem showing summaries of the status and trend analyses for each segment for the period of 1985 through 2007 for the SAV growing season. Abbreviations for each parameter are: TN=total nitrogen, SDIN=dissolved inorganic nitrogen, TP=total phosphorus, DIP=dissolved inorganic phosphorus, CHLA=chlorophyll *a*, TSS=total suspended solids, SECCHI=Secchi depth, DO=dissolved oxygen. The prefixes S and B refer to surfaceand bottom measurements, respectively. The presence of two trend symbols indicates a significant difference between pre- and post-method change trends. For such cases, the first symbol represents the pre-method change result while the second symbol is the post method change result.

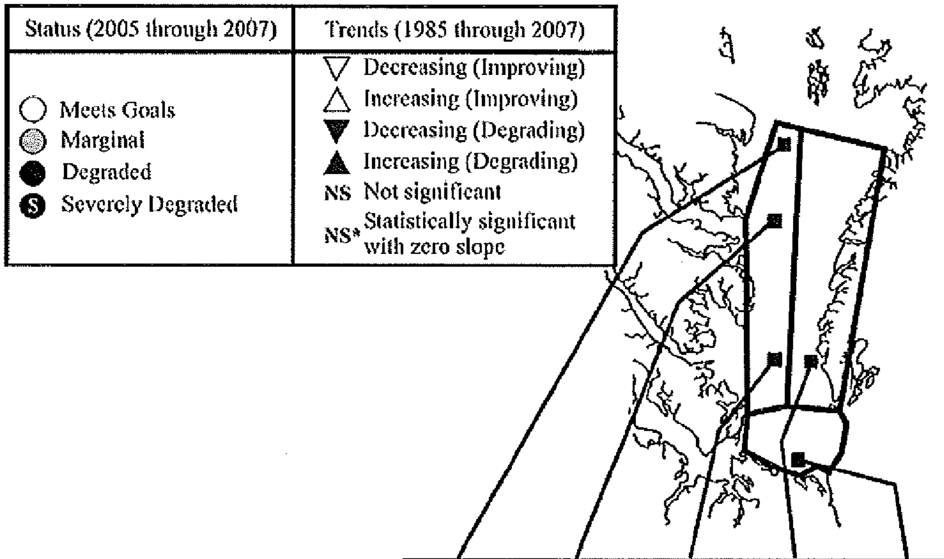
Status (2004 through 2006)	Trends (1985 through 2007)
○ Good Ⓕ Fair-Good ◎ Fair 🅕 Fair-Poor ● Poor	△ Increasing (Improving) ▲ Increasing (Degrading) ▽ Decreasing (Improving) ▼ Decreasing (Degrading) NS NSot significant * Season specific trend ↓ Decreasing ↑ Increasing



	CB6.1	CB6.4	CB7.3E	CB7.4
Phytoplankton IBI*	◎ NS	◎ NS	◎ NS	Ⓕ NS
Total Biomass	NS	NS	NS	↑
Biomass to Abundance	NS	△	△	△
Margalef Diversity Index	NS	▼	NS	▼
Productivity	NS	▲	NS	▲
Diatom Biomass	NS	NS	NS	△
Dinoflagellate Biomass	NS	▲	NS	▲
Cyanophyte Biomass	▲	▲	▲	▲
Chlorophyte Biomass	NS	NS	NS	NS
Picoplankton Biomass	▽	▽	NS	NS
Cryptophyte Biomass	↓	NS	NS	NS

* Status and trend results present for the Phytoplankton IBI were through 2006 due to data availability.

Figure 31. Map of the Virginia Chesapeake Bay Mainstem showing summaries of the status and trend analyses for the Phytoplankton Index of Biotic Integrity (P-IBI) and trend analyses of other phytoplankton bioindicators for each segment for the period of 1985 through 2007. Note that analytical results for the P-IBI are through 2006 due to data availability.



	CB5.4	CB6.1	CB6.4	CB7.3E	CB8.1
Benthic IBI	Ⓢ NS	◍ NS	○ NS	○ NS	○ NS
Total Abundance	NS	△	△	NS	NS
Total Biomass	NS	NS	▼	NS	NS
Pollution Sensitive Species Abundance (%)	NS	NS	NS	NS	NS
Pollution Indicative Species Abundance (%)	NS	▲	NS	NS	▽
Pollution Sensitive Species Biomass (%)	NS	NS	NS	NS	▼
Pollution Indicative Species Biomass (%)	NS	▲	NS	NS	NS
Shannon-Weiner Diversity Index	NS	NS	△	NS	NS

Figure 32. Map of the Virginia Chesapeake Bay Mainstem showing summaries of the status and trend analyses for Benthic Index of Biotic Integrity (B-IBI) and associated benthic bioindicators for each segment for the period of 1985 through 2007.